STAT

PLASTIC REPRESENTATION OF RELIEF ON MAPS

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ANNOTATION

This work deals with ways of representing relief on maps by means of shadow and draws on the experience of cartography both in this country and abroad. Descriptive information is provided on the method, techniques and color combinations used in plastic representation, as well as on the technology involved in the preparation of relief maps and its applications to the representation of relief by means of shadows.

The book is intended as an aid both to active cartographers and to students of institutions of higher learning specializing in cartography, in their study of techniques and practical exercises in the representation of relief by means of shadows.

FOREWORD

The plastic representation of relief on maps has now been in use for over 100 years. Yet many of its aspects still need to be explored. It still cannot be said that our knowledge is adequate as to the desirable properties of the image conveyed, the characteristics of particular color combinations, and the method and techniques

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to be applied in producing the image. The filling in of existing gaps in this field is one of the problems faced by cartographers ~~working in it~~.

The object of the present work is to examine the basic means, technical procedures and methodology involved in plastic ~~reproduction~~ rendering. The author has aimed at a clear and simple exposition of problems relating to the representation of masses and space on a map, through a description not only of the means and procedures applied at various stages, but also of their relation to one another, and the place each occupies in the entire chain of procedures involved.

This work attempts to draw generalizations both from published research and from the methodological and technological experience of production.

The theoretical foundations of plastic representation still remain to be adequately elaborated. It is only natural, in a work that reflects the contemporary status of our technques, that certain conclusions have to be qualified as provisional. Further experience and research in specific phases of the problem, such as plastic techniques in color, may ultimately lead to the revision of some of the views that are now current.

Our work has its share of inadequacies and inaccuracies, as may be expected in view of the paucity of research in the field. The author welcomes all suggestions aimed at improving this book.

The color illustrations appearing in this book were prepared in the course of research at the Central Research Institute of Geodesy, Aerial Photography and Cartography (TsNIIGAiK), directed by the present author. Printing processes are responsible for some loss of quality in the half-tone and color illustrations.

The author wishes to express his gratitude to G.P. Davydov, Candidate in the Technical Sciences, who assumed the responsibility for editing this book, and to S. G. Tikhomirov, for his critical reading of the manuscript and a number of suggestions that improved the text in certain section.

INTRODUCTION

1. The visual representation of relief on maps

The representation of relief is one of the more important and fundamental elements of a map. A wide range of practical problems which come up in various sectors of the national economy, require the use of maps and the representation on them of various features of relief on the earth's surface.

Cartography, throughout its history, has made use of a variety of means for representing relief, and these differ from one another substantially both in technique and in visual effect. However, for all their diversity, the main purpose of all these procedures is to convey on a map, e.g. on a flat image, not only the outlines of the distribution of

relief forms in two dimensions, but also the relationship in altitude of specific points, surfaces and elements of relief. Thus, the representation of relief differs from other elements entering into a map in conveying, in 2 dimensions, the characteristics of the relief of the earth's surface in 3 dimensions.

Depending on the visual properties of the means used to convey relief, the result is variously perceived.

In some cases, for example, use is made of the metric properties of the means employed. Such is the case in the representation of relief by means of contour lines. Contour lines, which are lines joining points of equal altitude, are widely used in cartography, and yield an image whose properties are essentially objective. They make it possible to determine the altitude of the elements of relief that are represented, and to appreciate the direction of slopes, elevations and gradients Yet they do not convey an overall, visual image of the relief.

For this reason, cartography often has recourse to multiple means of representing relief. Other means are thus used jointly with contour lines to facilitate the reading of relief.

A means for effectively conveying relief is particularly needed in maps intended for general use. The general map reader is mainly concerned with being able to appreciate at a glance the nature

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of the relief that is represented, its distribution in the area of the map, and ~~xxxxxxxxxxxxxxxxxxxxxxxx~~ its altitude and spatial extent.

This explains the need of plastic, or spatial representations of relief, which allow the visual appreciation of its nature and distinctive characteristics.

2. The fundamentals of plastic representation.

A representation that conveys visually the mass, three-dimensional quality and depth of an image is called a plastic or spatial representation.

This definition of plasticity stems from the Greek word "plastos" (modelled). Originally, the concept of plasticity was applied to art that reproduced three-dimensional models (sculpture). Subsequently, plasticity came to acquire a wider meaning, applied, on the one hand, to three-dimensional bodies in space and, on the other, to their representation on a plane. When applied to a flat image, plasticity denotes that property of the image which allows the visual perception of the space, mass and depth characteristics of the image as a whole and in all of its parts.

One of the means making it possible to create a visually effective plastic image is chiaroscuro. Chiaroscuro involves a scale of graded tones from light to dark, used in the representation of space and mass on a flat surface. The term "chiaroscuro" is also used to denote the degree to which specific points, both in an image and in an actual solid object,

are lighted as a result of their position in relation to an [illegible] source of light. Gradations of light and dark are used to reproduce the effect of mass, three-dimensionality and depth in an image. To denote degrees in the scale from light to dark, certain terms have been arbitrarily chosen: highlight, light, half-tone, reflected light, own shadow, and cast shadow.

Various branches of art and technology have made extensive use for a long time of chiaroscuro as one of the most convincing means for the visual conveyance of reality.

The effectiveness and realism of chiaroscuro as a visual means derive entirely from reality, e.g. from the regularities existing in the distribution of light and shadow on real solid bodies under specific conditions of lighting.

These regularities find their application in all forms of objective representation. They are one of the chief means at the disposal of the artist in the conveyance of reality. The correct rendition of the relationships between various components of chiaroscuro, e.g. own shadow, reflected light, etc., is fundamental to the representation of solid bodies.

Chiaroscuro has been apllied to the visual representation of relief in maps for a considerable time. As cartography has progressed, the techniques used to represent relief (hatching, shading, tinting)

have varied with the techniques of reproduction available for the publication of maps. However, regardless of technique, the quality of the image i.e. the effectiveness with which mass was conveyed, has always depended on the complete and correct application of the principles of chiaroscuro.

In addition to chiaroscuro, cartography also makes use of color combinations to represent relief. These combinations have been based on various principles. Thus, colors may indicate gradations in altitude, or stand for degrees of illumination of slopes, etc. In some cases, color combinations may convey the effect of shadows, in others they may not aid the perception of the solid qualities of the image, and in others still, they may not only fail to aid but, on the contrary, may inhibit the spatial perception of chiaroscuro.

This variability of effect is to be explained by the fact that color combinations vary in their optical properties depending on their component colors.

To obtain an effective image, it is necessary to know the properties of specific color combinations, and to establish a definite color scale on the basis of the properties of these color combinations.

The perception of various color combinations and their effect they create is not uniform for all observers. There exist appreciable variations in

the manner in which color combinations are visually appreciated. It is this fact that makes imperative a systematic study of all factors, both objective and subjective, affecting the process of visual color perception. The study of color perception is only a preliminary step. Yet, even the most casual and superficial observations serve to demonstrate definite relations between specific color combinations and their apperception. These relations have become established in the course of man's creative activity through history, which has been taking place in an universe of phenomena and objects characterized by an extreme variety of ~~xxxxxxx~~ chromatic gradations.

Thus, the methodology behind the creation of a spatial image of relief derives from: a) the application of the principles of visual art, and b) the application of the concepts of color science, that deals with the relations of color and its perception.

3. The distinctive features of the spatial representation of relief on a map.

The specific properties of the map serve to determine the methodology of the spatial representation of relief.

The ~~xxxx~~ major distinctive feature of ~~x~~ cartographic representation is that it is a two-dimensional ~~representation~~ image, in the form of an orthogonal projection. The line of sight is thus directed vertically at every point of the image, i.e. all the features represented on the map are viewed from above.

On the other hand, in a pictorial representation, the line of sight is horizontal, and all features are viewed from the side.

At the same time, ~~their~~ shapes, outlines, dimensions, superimposition, as well as the shortening of distances through perspective and other modifications following from the laws of linear perspective, are perceived. On the other hand, objects observed in an orthogonal projection and, in particular, the features of relief, lack these characteristics, and foreshortening as a result of perspective does not occur.

Therefore, linear perspective, ~~[illegible]~~ such as serves to convey spatial relationships between objects viewed from the side, is not applicable to the representation of relief on a surface.

In addition to linear perspective, aerial perspective is also involved in conveying the effect of distance both ~~for~~ along a horizontal and ~~for~~ along a vertical line of sight. The principles of aerial perspective find their application both in the monochrome and in the polychrome plastic representation of relief.

In selecting a scale of colors, it must be taken into account that certain colors serve to represent other features (for example, bodies of water are colored light blue and blue). To maintain the distinction between various ~~features~~ elements represented on the map, it is advisable to avoid such colors in representing relief.

Aerial perspective is discussed at greater length in Chapter III.

Is coloration applied to relief in accordance with what we might see in a particular terrain viewing it from above? Anyone who has observed relief from above (for example, from a plane), is aware of the fact that, in most cases, the landscape below is rather monotonous in color, consisting mainly of of greyish, grey-green and brown shades which would hardly be very expressive if incorporated in a representation. However, it is possible to observe in nature a considerable number of color variations depending on the terrain, the time of year, the day, and light conditions. These colors, occuring in the real environment and dwelling in our memories as ~~representative~~ representational color masses, make it possible to convey on a map, through color combinations, features of relief that have a ~~xxxxxxxx~~ live, realistic and visually-effective quality.

It should be noted that, among the solid forms of relief, certain shapes are absent, such as spherical ones or ~~xxxxx~~ those following inverted geometric bodies (such as the inverted cone, the inverted pyramid, and so forth). ~~The~~ Features of relief dealt with are wider at the bottom than at the top. This limited range of forms, as compared with that which is familiar to us from daily experience, affects the methodology of their representation, in

particular the use of the cast shadow, reflected light, and so forth.

Most maps, unlike other types of representations, are combinations of linear and tonal elements. Among linear elements, we may mention the representations of streams, roads, population centers, etc., as well as much of the lettering that occurs on a map. Among tonal elements, we find the representation of the spatial features of relief, and background coloring. All elements, linear as well as tonal, must be sufficiently readable. The coordination of all the elements of a map with a view toward preserving their readability is one of the more important concerns of cartography, and must be taken into account in attempting to create a spatial representation of relief.

One of the most important features of cartographic representation, as opposed to pictorial endeavor, is the need to localize accurately all the elements on a map. An artist deciding upon the composition of a painting, may vary repeatedly the distribution of the figures and objects he is conveying, to achieve the expressive portrayal of his main themes and to emphasize the basic concept he is putting across.

The objects and phenomena conveyed on a map are placed in accordance with their position on the terrain. Their re-location to achieve a more expressive

effect cannot take place, since the map would then fail to convey their true relationships. In this connection, the contrasting of high features of relief of slight gradient among low features of considerable gradient presents certain difficulties.

We have outlined the main distinctive features of a map that affect the methodology of the representation of relief. The manner in which these features and others are dealt with will be examined subsequently.

4. The spatial representation of relief as a creative process.

The products of representational art, in particular those of painting, are easy to grasp and to comprehend, and allow an easy appreciation of the phenomena conveyed only when they truthfully, expressively, and visually reflect reality in artistic form.

These conditions apply fully to the spatial representation of relief. The accurate conveyance of relations between light and dark, of natural coloring, and the use of aerial perspective make it possible to depict relief descriptively and artistically, and allow the reader of the map to discern the features of relief with ease, accuracy, and rapidity.

But to master the representation of relief is not merely to control the techniques of chiaroscuro

and a particular color scale, and then to apply these in accordance with the properties ascribed to them in uncritical fashion.

The spatial representation of relief through shading is a creative process, which requires a knowledge of the properties and relations inherent in a representation, and a conscious and critical use of this knowledge.

The representation, as it is created, must be constantly evaluated visually and controlled by the draftsman from a perceptual point of view. The draftsman must constantly ask himself whether he has found and conveyed in his representation that which is salient or typical in each form or combination of forms.

Through this control and evaluation, the draftsman continues to perfect his representation as he gradually approaches the completion of his task. In the course of this process, it is important to preserve all the time a feeling for the whole and for the relationship of parts within the representation.

Yet, the ability to control visually and to evaluate the image created is not achieved without effort. It is the result of systematic and continuous training, of accumulated experience in the representation of mass and space. Anyone working in this field must carry on continuous and systematic

observations of solid objects around him, sketching them and making use of the techniques of chiaroscuro and color combination.

Drawing from nature, from memory and from imagination and the exploration of varying color compositions are indispensable exercises to acheive control of the spatial representation of relief. In this connection, it is imperative to investigate the effects of specific techniques on the representation of relief, and how they contribute to it when their use is intensified or exaggerated. The purposeful exaggeration of certain techniques may, on occasion, have a beneficial effect, a circumstance which must be allowed for. Conversely, certain techniques that are effective in drawing solid objects from nature, may have adverse effects in the representation of relief.

The creative approach is not manifested merely in the creation of an original draft or the preparation of a sample. One of the important stages in the process is the reproduction of the created image by means of color printing. Color printing requires the visual analysis of a polychrome image into its component colors, into the corresponding printing inks, and the determination of the number and nature of the needed frames.

Visual color analysis requires, apart from technical experience in polygraphy, a profound

knowledge of the properties and relationships of colors, as well as practical experience in color work.

The spatial representation of relief is a phase of cartography that requires, above all, the use of methods pertaining to the visual arts, as well as a knowledge of color. It requires a creative approach throughout all the stages of the process.

Chapter I

TECHNIQUES FOR THE REPRESENTATION OF RELIEF THROUGH SHADOWS

5. The relation of techniques for representing relief to the technology of map printing.

By comparing the chiaroscuro representation of relief on maps published in different periods, it is possible to note that the nature and quality of representation have varied, sometimes considerably, from stage to stage in the development of cartography.

In addition to the requirements set for the image, and the content which the latter was given, the techniques available for production and printing have influenced these changes. Techniques of representation and techniques of printing are closely connected. Each of the existing printing techniques requires the creation of a draft by hand, to be used as an original or as an original printing frame.

The basic procedures that have been used in printing

maps over the last two centuries are engraving, lithography, and photo-mechanical processes. These procedures may be used separately or in combination. The technical requirements of each are served by the following means on the hand-drafted original: hatching, shading, and tinting.

Originals executed by means of hatching, shading or tinting, will differ in visual effect. The first will consist of a variety of linear patterns. The second will be formed of dots of unequal size, resulting from the rough texture of the background to which the shading is imparted. The third will be perceived as a continuous pattern of half tones. However, a three-dimensional quality may be achieved, to an equal degree, by all three means, other things being equal.

Three-dimensional quality depends not on the drafting technique used, but on the correct usage of the principles of chiaroscuro for given lighting of the relief. To correctly use the principles of chiaroscuro, whatever the technique of representation, experience and skill is required of the artist, who must know the laws governing the distribution of light and shadow.

Any original, drafted by means of one of the technical procedures enumerated above, is intended for reproduction in print. Any one of the printing techniques employed must reproduce completely, without loss or distortion

the image of the original. The quality of the image on printed maps thus depends not only on the execution of the original, but also on how it is reproduced in print. The technology of each printing procedure, as well as the experience and skill of the printer, will be reflected in the result.

In discussing the relation of drafting techniques to printing techniques, mention should be made of those means of representing relief that are used in manuscript maps, executed in a single or a limited number of copies.

The techniques of rendering relief on maps which are not limited by the technology of printing allow a broader exercise of creative ability. For this reason, manual drafting techniques for rendering relief deserve considerable attention.

6. Manual drafting of plastic representations of relief.

A manual draft may be executed in ink, water colors, oil paints or other types of paints used in portraiture or other kinds of painting.

Depending on the use for which the map is designed, the manual drafting of relief may be executed jointly with all other features that constitute the content of the map, or only with certain ones. Such, for example, is the combination of relief and drainage.

As an example of hand drafted plastic representation of relief, we may cite the "Atlas of the Campaigns of Russian Troops in Switzerland under the General Command of Generalissimo Count Suvorov Rymnikskiy, Prince of Italy ... in the year of 1799".

Aerial perspective is used in the representation of relief on the maps in this atlas. Thus, prominent mountain chains and peaks are rendered in light and warm colors: yellow and orange hues, emphasized by means of contrasting light and dark shading. In areas of lesser elevation, the colors tend to be colder; they are overlain with a bluish film of mist and shadows are washed out, suggesting space and distance, so essential in rendering mountainous relief. Areas of snow and glaciers are also rendered in light and dark in pale blue. The color scheme employed consists of tones occuring in nature.

The mastery apparent in the execution of all features in these maps is justification enough to consider this atlas as one of the outstanding creations of Russian cartography.

Many modern hand-drafted maps making use of color and chiaroscuro in the rendition of relief are testimony to considerable skill on the part of the draftsmen, who show themselves capable of conveying the content of their maps in a visually effective, easily understandable and artistic form.

It is characteristic of such maps that the means

used in their execution are inspired by reality in their use of light and shadow, aerial perspective, color relations, etc.

All these maps are, for the most part, single copies. Yet this does not detract from their value. On the contrary, they are significant in providing samples for attempts at reproduction in print and incentives to the development of technologies suited to convey in print the artistic rendition of their contents.

7. The use of hachure in the plastic representation of relief.

Hachure was used in rendering relief distribution as early as the XVIIth century. Hachures oriented parallel to slopes were, for the most part, equally thin throughout their length, and failed to convey other characteristics of relief. Yet, the appreciation of gradients on maps used in military operations was necessary in planning various types of troop movements.

In the XVIIIth century, the representation of relief changes, and obeys the principle "the steeper the slope, the darker the hatching". Representational techniques on hand-drafted maps vary. Sometimes, they involve hachuring executed with a brush and india ink diluted with water. At other times, they include tinting, with gradual variations of shading, or hatching executed with a pen.

At that time, no means existed for the reproduction in print of gradual transitions in shading. As a result,

printed maps made extensive use of hachuring reproduced by means of engraving on metal.

In the representation of relief through hachuring, a central role is played by the relation of light and dark and black and white, acheived by varying the thickness of the hatched lines, the width between hachures, and the density of the hachures.

Increased density or thickness of hachure served to convey shadows of varying intensity, corresponding to varying slope gradients. The steeper the grade, the more hachures occured in a specific area, or the greater the thickness of the hachures used. All hachures were oriented longitudinally in relation to the slope.

Illustrations of hachuring technique are to be found in the scales, devised toward the end of the XVIIIth and the beginning of the XIXth centuries for use in rendering relief.

Note should be made of the Lehmann scale, devised toward the end of the XVIIIth century for representing the relief of Germany on military topographic maps. The representation of relief in accordance with this scale, requiring an accurate measurement of the number and thickness of hachures to be found in ~~an area of specific size~~ a specific interval, was a very complex process, particularly for pencil work in the field or on a preliminary draft. The scale was suitable mainly for the representation of the relief of southern Germany.

In the beginning of the XIXth century in Russia, scales were devised by Professor Boltov of the Military Academy and the Section of Military Topography of the General Staff. These scales were geared to the lowland relief of Russia. The principle on which these scales were based involved a determination of the distance between the axes of hachures and did not require a particular spacing of hachures within an interval of specific size. It was considerably simpler than that used in the Lehmann scale. One of the major works executed by means of the scale employed by the Section of Military Toography of the General Staff was the three-verst map of European Russia, whose publication began in 1845 (Fig. 1).

Hachuring was not only to represent relief on the principle "the steeper the slope, the darker the hatching" in accordance with definite hachure scales. A number of maps show relief by means of hachures conveying shadows derived from lighting relief from the side. Among the larger and more important projects executed in this manner, we may mention the topographic map of Switzerland (1836-1865) on a scale of 1: 100,000 (by Dufour)*

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* Topographische karte der Schweiz, G.H. Dufour 1: 100 000, 1865.

The rendition of relief on this map has a three-

dimensional quality.

In the reprsentation of relief by hachuring it is possible to have the hachures not only follow the orientation of slopes, but also cross one another in a variety of directions. Hachuring may be entirely random, or may consist of hachures oriented in a definite manner. An example of the latter procedure may be seen in Schinert's scale, devised toward the beginning of the XIXth century to represent relief in accordance with the principle "the steeper the slope, the darker the hatching" and judged by his contemporaries to be more manageable than Lehmann's scale**.

** Schinert's scale is described in the book " Concerning the General Situation and, in Particular, the Drawing of Mountains Following Mathematical Principles" by Major T., St. Petersburg, 1811.

The extensive use of hachure in cartography was greatly encouraged by the development of engraving which, to the end of the XVIIIth century, remained the only technique for the reproduction of illustrations***.

*** Information on the technology of engraving on metal may be sought in "The technology of map publication" by V.V. Pus'kov, Moscow, Goslitizdat, 1950. Various

types of engraving are described in "Outlines of the history and technology of engraving", published by the State Museum of Representational Arts Imeni A.S. Pushkin, Moscow, 1941.

For cartography, engraving was a high-grade, effective technique of rendering relief through hachure in print. Engraving allowed the wholesale reproduction, without distortion, of all varieties of relief representation through hachure, making use of differing principles and of hachures of varying length and width, including extremely thin ones.

As a technique for the publication of maps, engraving continued in use successfully in the XIXth century, when other forms of printed illustration already made use of other means of reproduction, such as lithography.

Hachure remained the principal technique used in topographic maps throughout the XIXth century. Even relatively late, toward the end of the XIXth and in the beginning of the XXth centuries, when engraving had been replaced by other means of map reproduction (lithography, and then photo-mechanical techniques), hachure continued in use as a means of representing relief on various maps.

This period is noteworthy for the use of color printing in cartography, which found applications in

the rendition of relief. For example, it is possible to find school maps in which relief is represented through hypsometric coloration in combination with hachuring and side lighting. Hachures were usually rendered in brown.

Hachure requires considerable skill. At the same time, it is time-consuming and, for this reason, expensive, which is one of its main disadvantages.

In addition to being highly representational and allowing the use of a variety of principles, hachuring also has a number of technical advantages.

Hachuring allows:

a) the use of a variety of printing techniques: engraving, lithography, photo-mechanical techniques, and combinations thereof;

b) the use of any color to represent relief, for contrast with other features on the map;

c) the rendition in print of the original drawing completely, without losses or distortion.

Considering that hachure does not require elaborate photography through a grating, it may quite justifiably be used in conveying relief three-dimensionally on modern maps.

8. The spatial representation of relief by shading.

A technique widely used in art is that of chiaroscuro drawing executed in pencil or charcoal on a textured paper. If magnified, the chiaroscuro in such a drawing appears as an assemblage of separate

elements, in the form of irregular spots of varying size and outline, situated on the protrusions of the paper and resulting from pencil strokes. When pressure is applied, the spots become large, and the shadow appears dark. When pressure is lifted, the spots diminish, and the shadow becomes lighter. If pressure is gradually varied on the pencil, the shading will grade from dark to light. This procedure may be used in rendering the three-dimensional rendition of relief. It is called shading.

An appropriate technology is required to reproduce shading in print. Engraving, which can convey a linear design, cannot convey a shaded representation in print. The technique that allows the reproduction of shading is lithography, i.e. printing from a lithographic slab*.

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* P.I. Suvorov. The art of lithography. Moscow, 1952.

An original shaded representation, executed on a lithographic slab, serves as a printing frame. To allow the representation of relief through shading, the stone is first given a rough, grainy texture by [illegible]. A stone treated in this manner to give it a granular surface is called "[illegible]". The image is executed on the "[illegible]" stone by means of a special lithographic pencil. Shading may be executed on other materials than stone, such as special roughened

paper (autographic paper) or on ~~copperplate~~ zinc, aluminum, etc., which then serve as printing frames.

Shading is a very valuable technique for artistic half-tone drafting. Ample evidence for this is to be found in many examples of autolithography, one of the types of lithography applied in the mass reproduction of illustrations executed by outstanding artists.

As an example of the use of shading on maps we may adduce the map of the ~~xxx~~ border area of the Asian part of the USSR on a scale of 40 versts to the inch. Relief in this map is rendered under combined lighting: side lighting for shaded slopes and top lighting for lighted slopes. To contrast the two slopes, mountain chains are represented as white lines. This combination of lightings is not entirely satisfactory, since it tends to decrease the spatial effect of the representation and to convey inadequately the nature of the relief.

Relief is conveyed in a more expressive manner through shading on a map of Bulgaria published in 1950 (Fig. 2). ~~The xxxx~~ representation of ~~xxx~~ relief is rendered with a consistent use of side lighting*

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* Bulgarian People's Republic, scale 1: 400,000, Sofia, Institute of Geography, 1950.

Shading may convey relief through the use of a number of principles: vertical lighting, side lighting, etc.

Lithography, invented in the end of the XVIIIth century, soon became firmly established as one of the more important techniques for printing illustrations, allowing, as it did, to reproduce half-tones cheaper, faster, and on a more extensive scale than engraving. Under conditions of private enterprise in the industry, these advantages were decisive in determining the choice of technologies in printing.

Meanwhile, the acceptance of shading as a means for representing relief in cartography took place slowly and in the face of numerous obstacles. One of the main reasons for this was the necessity to modify and adapt the process of map printing to make use of it.

In the XIXth century, every sheet of a map printed by means of engraving, was put out in a single color, i.e. by using one printing die, which also reproduced the hachured representation of relief.

The use of shading required an increase in the number of colors used, the preparation of a special die on a Kopfsteinstein stone, the use of multiple printing (shading by means of a stone, and other features by means of engraving), or a conversion from the preparation of engraved metal frames to the preparation of stone dies. All these innovations were resisted

by an industry well adjusted to metal engraving, all the more since early lithographs were not of sufficiently high quality.

The need for a cheaper printing process to increase profits was not felt asstrongly in cartography as it was in the book and print industries, since maps were sold in relatively small quantities. Most of map production in the XIXthe century was aimed at satisfying the needs of the military.

One of the main reasons for the slowness with which shading as a technique penetrated into carbography was the distinctive quality of the shaded drawing and the way in which it differed from hachured representation. The basic element of a hachured representation is a sharply drawn line of definite length and heaviness. On the other hand, a shaded representation includes no elements of established dimensions, and is perceived only as a whole, as a drawing with light and shadow, and not as a combination of representational elements.

In the beginning of the XIXthe century, when the hachured representation of relief had become firmly established and conformed to standards set for it, which involved the characteristics of individual hachures, it was only natural that the same standards were applied to shaded representation. Shading could not come up to these standards, and this prevented its use in map drafting.

The earliest attempts to use shading on a stone in the half-tone rendition of relief date back to 1816*. Nevertheless, the technique of hachuring

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* In a letter dated 7/2/1816, quartermaster Col. Diest, stationed in Berlin, requested permission to acquire a printing press for typographic printing (stein - druck), indicating that this method would be worth using to represent relief on topographic maps. Enclosed with the letter is a small test print, showing a cluster of relief features and a landscape with shading. The reply he received advised him of the fact that this acquisition was unnecessary, since lithographic equipment had already been purchased and shipped out of Munich. This equipment was used both for printing illustrations and in reproducing maps and plans at the Military Topographic Office. (Quoted from an MS by K.A. Borodina, "Toward a history of lithography in Russia", 1950).

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continued in use for a long time as a means of rendering relief, to the end of the XIXth century and the beginning of the XXth.

It should be noted that shading requires considerable skill, and is a highly expressive technique. The drawing, as executed on a stone or

on autographic paper, is faithfully reproduced in print by relatively simple technological means.

Shading allows for variations in technology, and ~~xxx~~ may perfectly well be used in modern maps, particularly wall maps, for the plastic representation of relief. The growing use of transparent materials in map making, such as vyniprose, opens possibilities for the execution of half-tones on "~~xxxxxxxxxx~~" vyniprose and ~~xxx~~ the direct ~~xxxxxx~~ duplication of the image on a printing die without the intervention of photography.

9. The representation of relief through tinting.

The XXth century is ~~x~~notable for the development of photography ~~xx xxx~~ for reproduction. Photography is widely used in the printing of illustrations. The publication of maps is also largely converted to photo-mechanical processes.

The technology of the photo-mechanical processes is used in printing a half-tone image is quite varied. The most widespread photo-mechanical technique for the reproduction of a spatial representation of relief requires the execution of relief ~~with~~ in black india ink or water colors on white paper. The representation consists of continuously graded half-tones varying in range from black to white. ~~xxxxxxxxxx~~ The technique used to create an original of this kind is called tinting, and the printed representation resulting on maps is also called tinted.

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The tinting in of relief was used as early as the XVIIIth and XIXth centuries f hand-drafted maps, but became current only in the XXth century, being applied on a variety of ~~many~~ educational, topographic, and reference ~~and~~ maps, as well as in specialized maps esigned for various purposes.

Tinting has a number of advantages over hachuring and shading. In tinting in relief, the simplest technique and materials may be used: india ink or water colors, and a brush.

The process of tinting requires much less time, particularly compared to hachuring. The visual appreciation of an image executed through tinting is much more direct than that of a hachured or shaded representation, since tinting allows a continuous gradation of half-tones in the original, approximating the true distribution of light and dark ~~in~~ on solid objects.

However, tinting, and particularly its reproduction in print, offers certain drawbacks.

The technology involved in the printing of tinted representations differs from that in reproducing hachured or shaded images. The hachured or shaded original is executed directly on the printing die, while in the reproduction of a tinted representation, an intermediary stage intervenes between the execution of the original and its reproduction. It is the photographic stage.

In earlier processes, the original, executed directly on the printing die, was then printed directly on paper. The direct contact between the original and printed images was conducive to the complete rendition of the original in print. This may be illustrated by means of numerous examples of maps, printed directly from engraving and lithographic frames, which reproduced the original. Even the conversion from original to machine-made dies hardly distorted the original image.

As a result of the introduction of an intervening process, that of photography, the image loses some of its characteristics. An original may be of high grade, yet its reproduction may incur considerable distortion and be of low quality.

The main cause of distortion is the use of a grating * in the photographic process. In photographing

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* The grating is a grid of dark lines on glass or some other transparent medium, usually oriented along two perpendicular axes. A grating is used in the camera for photographing half-tone originals to break down a continuous half tone into individual points on the negative.

The dark elements of the grid fail to transmit light rays reflected by the image, causing the occurence on the reproduced image of minute grains, both in its lightest and darkest areas (dark and light grains,

respectively).

Techniques of reproduction and the use of the in reproducing cartographic half-tone originals are described in V.V. Pus'kov's "The technology of map publication", Moscow, 1940.

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the scale of half-tones present in the original through a [illegible], the scale, which contains gradations from white to black, is either abbreviated to a scale ranging from dark grey to light grey, or is modified in its tonal relationships. The abbreviation and modification of the scale of half-tones modified and distorts the three-dimensional quality of the image.

With regard to the quality of the original, it is important to note that the basic requirements for the image, that of conveying the three-dimensional quality of relief features, is not always considered to be the ultimate one. In a number of cases, this requirement is superseded by others, equally important, that can be satisfied, however, only if the basic requirement is fulfilled. Thus, for example, the need is sometimes felt to convey only major orographic gradients, or the geographic nature of the features depicted, or else to exaggerate light and dark contrasts on the original to ensure a satisfactory reproduction, and so forth.

All these requirements have meaning only if the three-dimensional effect of the representation is preserved. If, in attempting to convey only major orographic gradients or to reinforce the contrast of

light and dark, the three-dimensional quality of the image is lost, and the result is a pattern of blots and smudges rather than a plastic image of relief, these requirements lose their meaning, since they refer to features of relief whose representation will be absent.

Lately, the quality of reproductions of tinted relief on maps has improved considerably. While in the recent past, maps were released whose tinting was of poor quality, maps published in recent years convey more satisfactorily the three-dimensional quality of relief. We may cite as an example the school map "The Pamirs and the Tien Shan", on a scale of 1: 1,500,000, put out by the Main Office of Geodaphic Maps of the Council of Ministers of the USSR in 1952.

The use of only one color in representing relief on modern maps constitutes a considerable drawback. To obtain a high-grade representation, which will be readable to the same degree as other features on the map, it is imperative to use varying color combinations. Yet, tinting is generally rendered in one color only on modern maps. Sometimes, maps are printed in two colors, but, by and large, the colors are too close to each other. Generally, they serve only to reinforce the contrast of light and dark (shade), darkening the representation of relief and reducing thereby the readability of other features of the map against the three-dimensional background. The use of such colors does not truly serve to broaden the color scale of the map.

Cartographic reproduction requires high-grade color originals, suscentible of being used as models for multi-color printing. Such originals are relatively rare. Their absence is impeding the use and development of 3-color, 4-color, and polychrome printing in cartography, which allow the printing of high-grade ~~xxxiaf~~ representations of relief.

Chapter II

FUNDAMENTALS OF THE RENDERING OF RELIEF BY MEANS OF SHADOWS

10. The rules of chiaroscuro.

An examination of several chiaroscuro representations of the same orographic unit, executed by different artists under similar conditions, will reveal a number of ~~xxxax~~ differences between these representations. Some of these differences may be trivial, and the features of relief will appear similar despite them. Others will reflect differing interpretations of the nature and features of the relief. Others still will result from insufficient knowledge of the rules of light and shade distribution.

To convey in a reliable manner the relief of an area on a map under ~~xxxx~~ given conditions of lighting, it is necessary to study the rules of chiaroscuro and their application to the features depicted and the conditions of lighting.

The task of the chiaroscuro artist consists in

conceiving and rendering the distribution of light and shade on various features of relief for varying conditions of lighting, on the basis of a study of chiaroscuro and practical experience. In executing a representation, he must select among several possible alternatives the one that will best meet the standards required and will be most conducive to conveying the three-dimensional quality and the features of the relief. In this process, a central place is occupied by the problem of how the user of the map will appreciate a particular mode of representation. The making of allowances for perceptual mechanisms is one of the important components of the creative process in executing a plastic representation.

Given artists with an adequate amount of training, experience, and understanding of the rules of chiaroscuro, representations of the same terrain produced independently will differ inconsequentially from one another. Differences will consist largely of varying degrees of generalization, and of differing renditions of certain details.

11. Type of lighting and its effect on light and shade.

One of the principal factors governing the distribution of light and shade on objects is lighting. The type of lighting may be varied by means of the medium through which the light beam is projected. On clear cloudless days, the light that reaches us from sun illuminates objects around us with a bright

light. Such light is called direct light. Sometimes, the sun is veiled by thin, white clouds. The intensity of the light at such times is considerable, but the clouds diffuse the rays of the sun, and we receive no direct light. Such light is called scattered.

In executing a chiaroscuro image, it is necessary to represent clearly the variations of light and shadow distribution caused by direct and scattered light. The type of lighting used depends greatly on the type of relief represented, and on the differences in elevation present in it. For example, to convey sharp, high-altitude forms, occuring in areas of high elevation, direct lighting is preferable, since it provides contrasting, sharply delineated shadows. In representing gently sloping, rounded features of soft outline, occuring mainly in areas of low elevation, scattered light is more suitable, inasmuch as it results in diffuse shadows of indefinite outline. Areas of low elevation are the farthest removed from the eye of the hypothetical observer, who is viewing the relief from above. At the same time, the thickness of the air layer between areas of low elevation and the eye of the observer is conducive to a greater diffusion of light reflected from these areas, and to the perception of soft boundaries between light and shade.

When they hit the surface of an object, light beams are reflected. In physics, two types of light reflection are distinguished: mirror reflection and diffused (scattered) reflection.

In mirror reflection, the incident beam and the reflected beam are in the same plane, and form equal angles to a perpendicular to the reflecting surface at the point of incidence of the beam. Mirror reflection occurs on smooth polished surfaces of varying composition, e.g. water, glass, etc.

An ideally mat surface providing a scattered reflection diffuses incident light equally in all directions. However, the reflective properties of mat surfaces in practice only approximate this ideal pattern of diffused reflection. While reflecting light in all directions, they nevertheless reflect light more intensely in a direction corresponding to that taken in mirror reflection. Such is the behavior of gypsum, porcelain, frosted glass, textured paper, and so on.

Both types of reflection occur on objects surrounding us, the predominant type being a combination of mirror and diffused reflection. Most varieties of paper, textiles, rocks and minerals provide mixed mirror and scattered reflection.

Reflected light is less intense than incident light. However, in lighting objects, it behaves as a factor affecting the distribution of light and shade. Scattered reflected light results in soft, indefinite shadow outlines, similar to those created by scattered incident light. Mirror-reflected light, like direct light, causes contrasting, sharply delineated shadows.

A ray of light falling on the surface of an object incurs multiple reflection, and this affects the degree to which objects are lighted, and causes variations in the nature, outlines and intensity of light and shadow on various objects.

The visibility of objects distant from the observer differs from that of objects that are closer. Outlines, coloration, light and shadow are perceived differently for distant objects than for close ones.

The cause of these variations is the atmospheric layer intervening between the observer and the object, and which, from the optical point of view, exhibits the properties of a translucent medium. A light beam traveling through the atmosphere is absorbed and diffused by atmospheric particles. Absorption decreases the intensity of the light beam, while diffusion changes its direction, causing it to scatter away from the intercepting particle in all directions, including that of the eye of the observer. In addition, diffusion affects the spectrum of the beam, thereby modifying the coloration of the objects lighted.

When a layer of air is irradiated by scattered light, an atmospheric glow or haze is created. Haze is bright and is always visible as a background for distant, darker objects.

The brightness of haze increases as a factor of a) the thickness of the air layer, and b) the degree

of illumination of the air layer in daylight.

When viewing distant objects, the brightness of the haze is compounded to that of the object, i.e. both these brightnesses are merged optically.

Atmospheric haze affects the apparent brightness of a distant object in two ways: a) it decreases the brightness of the object as a result of the absorption and diffusion of light; only a fraction of the original amount of light travels from the source to the object and from the object to the observer; b) it increases the brightness of the object by means of the light scattered by the air layer.

As a result of this simultaneous decrease and increase in brightness, the brightness of dark and light objects is equalized.

In a thick atmospheric layer, the brightness of haze equals that of a cloudless sky at the height of the horizon. All objects tend toward that degree of brightness as they are removed away from the observer. If the object's own brightness is less than that of the sky at the horizon, the object becomes brighter as it moves away from the eye (for example, trees). If the object's own brightness is greater than that of the sky at the horizon, the object becomes darker as it moves away (e.g. snow-capped mountain peaks).

As a result of the scattering by the atmosphere of light traveling from the object to the observer,

objects lose the sharpness of their outlines, and the boundaries between objects and their backgrounds become less perceptible.

The effect of atmospheric haze has applications in the representation of relief by means of shadows, with due account of the features required of cartographic representation.

The variation of the scattering properties of the atmosphere ~~in~~ horizontally differs from that of these properties vertically. In a perspective drawing, atmospheric haze will often obliterate entirely objects situated in the background at a considerable distance, ~~xxxxxxxxxxxxxxxxxxxxxxx~~ and these may not be visible or only faintly discernible. In depicting relief, atmospheric haze may be used only to a limited degree, since it must not ~~xxxxxx~~ obstruct a clear view of relief features at low elevations.

Both diffused and reflected light, always present in nature, are highly operative in affecting the lighting and the distribution of light and shade ~~on objects~~. Were it not for natural atmospheric scattering, ~~xx~~ there would be no half-shadows between light and shadow. All the objects around us would then remind us of a moonscape, and would appear entirely as a pattern of organtly lit and totally black surfaces. Were it not for light reflection, we would not observe such important components ~~xx~~ of chiaroscuro as reflected light and the deepening of shadows in areas of negative

space, that aid in appreciating the three-dimensional quality of objects.

For this reason, chiaroscuro representation requires the use of all elements of chiaroscuro: own shadow, cast shadow, reflected light, the deepening of shadows in areas of negative space, half-shadows, smooth transitions and sharp contrasts, all of which result of the presence of direct, scattered and reflected light.

All these elements are not independent but, on the contrary, are close connected one to the other. Their main function is to convey relief in a three-dimensional, visually convincing manner, so that its properties are retained in the resulting image.

12. Own shadow.

If we light a solid object, we will find that its various surfaces will receive varying quantities of light: some will receive more, others less, others still will receive none of the light issuing from the source.

On a sphere (Fig. 3), the more brightly illuminated surfaces are those receiving light at a right angle or nearly so. As the angle between the direction of light and the surface is decreased, the ~~xxx~~ degree of illumination of the latter will decrease. When the light merely grazes the surface (or, more precisely, when it follows a tangent to the surface), illumination will ~~max~~ equal zero. As illumination decreases, the intensity of shadow increases, varying from a minimum

value at point A to a maximum value at point B.

The line at which light rays emanating from a source touch the surface of a sphere divides it into two hemispheres: a lighted one, and an unlighted one. The former is accessible to light rays, the latter is not. The entire unlighted hemisphere is in shadow. The degree of illumination of this hemisphere should equal zero at all points and, hence, should be constant throughout. In practice, however, the degree of illumination of various points differs as a result of the effects of scattered and reflected light, which always occur in nature.

Light is distributed in the same manner over any self-contained solid object. The line formed by the points at which directed light rays touch the surface of the object divides the latter into two parts: an illuminated part, and a non-illuminated part.

That part of the lighted object which receives no rays of directed light, or receives them only in weakened form, is called the shaded area, and the shade which covers it is termed the object's own shadow.

A sphere's (Fig. 4) own shadow covers the unlighted hemisphere and that portion of the lighted hemisphere that is contiguous to the unlighted one and is poorly illuminated as a result of the fact

that light rays are tangential to its surface.

This portion is in the form of a narrow band, that constitutes a transition zone from the lighted to the unlighted hemisphere.

Own shadow is a basic element of chiaroscuro, used in representing relief. It serves to convey the nature and dimensions of shapes.

Fig. 5 provides a diagrammatic illustration of the distribution of own shadow on a crossection of some simple relief features.

If the depicted feature occupies a considerable area, it is conveyed by means of a long shadow*.

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* The length of own shadow is measured from the peak or crest of a feature to its base.

However, varying the length of the shadow will not, in itself, provide three-dimensional quality. The length of the shadow is an indication of the dimensions of the feature and is a starting point, making it possible to impart varying degrees of prominence to an object in conjunction with other techniques.

In addition to length, shadows also vary in their intensity. The same shadow may vary in intensity in its different parts. For example, in a number of situations, own shadow is rendered as darker along the edges than in the middle. This is usually done when the edge of the shadow coincides with a crest or a peak

that must be depicted as prominent. The use of this technique and the its visual effect is founded on the phenomenon of luminous (achromatic) boundary contrast.

Color studies have shown that two colors placed side by side affect the perception of each. For example, a light grey tone next to a ~~black~~ dark grey one will appear lighter, while a dark grey one next to a light grey one will be appear darker than it actually is. Such an apparent change of coloration is termed luminous contrast. Luminous contrast is most easily perceived ~~most~~ at dividing lines between colors (Fig. 6), and for this reason is called marginal or boundary contrast.

The phenomenon of boundary contrast also has the following property: every boundary between a dark and light color band appears as a protruding ridge.

In Fig. 6, the scale on the right-hand side consists of five evenly graded steps. Each step appears ~~lighter~~ lighter near its boundary with a darker tone, and darker at the boundary with a lighter tone. This results from the phenomenon of luminous boundary contrast. In addition, the scale as a whole is perceived not as a flat surface, but as a ridged surface, consisting of eminences and concavities. As a result of achromatic boundary contrast, the coloration of each step in the scale appears unequal, varying in intensity from one ridge to another. This is perceived

as light and shadow. If the apparent unevenness of each step in the scale is reinforced by additional coloration, as was done in the scale on the left in Fig. 6, the ~~xff~~ ridged effect is further intensified.

The ~~association~~ of luminous contrast and relief is acquired from nature. When we observed lighted forms and surfaces differing in degree of illumination separated by protruding ridges, we perceive those of their portions that adjoin these ridges according to the laws of boundary contrast: the light surface appears even lighter, while the dark one seems even darker. This association of luminous boundary contrast with the effect of relief finds extensive applications in the representation of solid forms through chiaroscuro. Own shadows, bordering sharply on lighted or, more generally, lighter surfaces, appear darker along ~~thxxx~~ their boundaries than on the remainder of their surface. The intensification of shadow produces an impression of relief along the boundary where the shadow is intensified.

If the form is rounded, the edges of the shadow appear indefinite where they pass into illuminated areas. If the form is defined by sharp, well-defined edges, as happens in the case of high mountain crests, the edge of the shadow is abrupt and ~~intxxxx~~ intensified to contrast with illuminated surfaces.

In a number of situations, to convey the nature of the relief requires the use of hachured rendering

to emphasize cliffs, gullies and other sharply defined features. Hachured drawing also accentuates the impression of relief, since boundary contrast is particularly operative in it.

The basic property of own shadow may be formulated as follows: own shadow accentuates the apparent projection of positive forms, on which it occurs; the darker, the more contrasting and the longer own shadow is, the greater the apparent projection of the feature represented.

13. Cast shadow.

Any opaque body that fails to let through rays of light casts a shadow in the direction opposite of that of the light source. This shadow falls on other bodies and surfaces and shields them completely or in part. This shadow is called cast shadow.

Cast shadow varies in intensity. First to be noted is full shadow, which is the darkest.

In addition to full shadow, there are peripheral areas of half-shadow. Half-shadow results from the fact that the light source is more than a point source in size.

Full shadow serves to delimit the area that is totally inaccessible to the light rays emanating from the source. The area of half-shadow is inaccessible only to a portion of the light rays. The closer the object to the surface on which the shadow is cast, the narrower the half-shadow and, conversely, the more distant the cast shadow from the object, the

broader the area of half-shadow.

Examples of this may be found in the shadows cast on a sunny day by various high objects (houses, towers, trees), which differ in length. The lower parts of the shadows near the bases of the objects, have well-defined outlines and consist entirely of full shadow. The upper parts of shadows consist both of full shadow and of less intense half-shadow (fig. 7). In connection with this phenomenon, a cast shadow with blurred edges is perceived, in a representation, as being distant from the feature causing it, while, conversely, a sharply outlined cast shadow is interpreted as indicating proximity between the surface on which the shadow falls and the feature causing the shadow.

Cast shadow may shield illuminated surfaces to varying degrees. ~~This~~ The degree depends both on the elevation of the feature casting the shadow and the elevation of the feature on which the shadow falls. As may be seen from Fig. 8, the shadow cast from peak A falls on the illuminated slope of peak B, which is higher, and obscures only the lower part of this slope, while the peak itself remains illuminated. At the same time, the shadow cast from peak B covers ~~xxxxxx~~ lower peak C, and obscures it entirely. Thus, the higher the feature, the more prominent is its illuminated portion; the lower the feature, the more it is obscured by cast shadows.

This regularity obtaining in nature finds its application in depicting relief. If the slopes and summit of a specific feature of relief are entirely covered by cast shadow, while another feature has only its lower slopes in the shadow, the summit remaining illuminated, the second feature will appear as more prominent than the first. The higher the elevation reached by cast shadow, the less prominent will the obscured feature appear.

Cast shadow may be used in a representation only when features exist that may cause it , since, in the absence of such a feature, the cast shadow will fail to be realistic and will not improve the image.

The outlines of cast shadows are determined by three factors: the direction of light, the shape of the feature casting the shadow, and the position of the surface on which the cast shadow falls. The line along which light rays touch the feature serves to delineate the outline of the shadow cast into space. The latter, when projected on a given surface, assumes the apparent outlines of a cast shadow. These outlines vary with the position, inclination and convolutions of the surface, and may differ considerably in outline from the shadow cast into space. For example, the line describing the shadow cast by a sphere into space has the form of a circle, whereas the cast shadow that occurs when light direction is not perpendicular to the surface has the form of an ellipse (cf. Fig. 4).

The contents of a map consisting, in addition to a representation of relief, of hachured symbols, labels and other features, substantially affects the perception of a chiaroscuro image. In turn, the latter also determines, to a great extent, the readability of other elements in the map. For example, if the representation includes intense shadow, its dark background will adversely affect the readability of hachured features on the map. If, on the other hand, the number of hachured symbols and labels is excessive, the spatial effect of a chiaroscuro image is thereby impaired. This factor, in particular, limits the use of cast shadow, which results in an expansion of dark backgrounds in a chiaroscuro image and yet, because of the considerable number of inked-in elements present, fails to add to the three-dimensional quality of the representation. In such cases, it is advisable to choose, in representing relief, a type of lighting that allows the greatest possible shortening of cast shadows, while still preserving the three-dimensional effect provided by other elements in the representation, and allowing the use of color combinations contributing to conveying the spatial effect of relief.

The basic property of cast shadow may be summed up in the following terms: cast shadow contributes to an effect of apparent recession of the features it covers; the more a relief feature is covered by shadow, the more this feature appears to recede.

14. Reflected light.

Light rays that strike a surface are ~~partially~~ in part absorbed by the surface, and in part reflected. Reflected light striking other surfaces increases their illumination.

This phenomenon is known as reflected light. Reflected light is also the effect of the reflection of light on a specific object. Reflected light is, for example, easily observed on a sphere, if the latter is placed against a light background. In this case, the part of the sphere opposite to the direction of the light should exhibit the deepest shadow. Yet it is precisely in this part of the sphere that we observe a light area, while darker shadow is to be found nearer to the illuminated portion (cf. Fig. 4). This lighter area is caused by a reflection, from the surface on which the sphere is placed, of the light reaching the portion of the sphere hidden in shadow. This light area ensures the perception of the ~~shape of the~~ form as a sphere resting on a surface only at one point. Cast shadow and reflected light make it possible to distinguish the image of a sphere from that of a hemisphere: a hemisphere will not show reflected light, since reflected light will skim the surface of the hemisphere without striking it.

The presence of reflected light is determined, to a considerable degree, by the nature of light reflection. If light were reflected only in mirror fashion, i.e. only in one direction, reflected light would be observed much less frequently, and would take the form of sharply

outlined, bright spots. Diffused reflection contributes to the appearance of reflected light in the form of dull areas ~~xit~~ of indefinite outline.

The use of reflected light in a representation must be based on conditions obtaining in actuality. If reflected light causes the appearance of light spots on certain objects, these objects should be depicted as ~~xxxxxxxxxxxxxx~~ i luminated by reflected light. In this, due account must be taken of the direction of the light emanating from the source, and of the mutual relation of planes horizontally and vertically.

If the planes present are inclined relatively little in relation to the vertical, and the distance between them is relatively small (Fig. 9a), plane A receives relatively intense light reflected from plane B. If planes A_1 and B_1 are inclined considerably in relation to the vertical (fig. 9b) and the distance between them is considerable, surface A_1 will receive reflected light from B_1 that will be so weak as not to be perceptible.

Thus, in representing features of gentle inclination and moderate prominence, it is not advisable to make use of reflected light. Reflected light is most applicable in representing mountainous relief, where slopes form relatively acute angles with one another.

Fig. 10 represents the mutual relation of a number of surfaces in a horizontal plane. Light reflected from surface A will illuminate noticeably

surface B C, less noticeably surface E, and still less surface F. It will fail entirely to reach surfaces B and G.

The effect of reflected light is particularly important in depicting irregularities that are covered by shadow. Without the effect of reflected light, all irregularities, eminences and other details situated entirely in shadow could not be perceived. Reflected light makes it possible to read them. However, the excessive use of reflected light may cause a cluttered image and lead to a loss of readability of the larger and more important features. For this reason, reflected light should be used only where it is justified by the relation of existing surfaces, the direction of the light, and the requirements of legibility of all features of relief.

Reflected light is always weaker than directed light as a result of absorption. Therefore, a surface illuminated through reflected light cannot be brighter than a surface illuminated through directed light. By its brightness, reflected light ranks as one of the gradations of shadow.

The visual qualities of reflected light may be formulated as follows: reflected light conveys the three-dimensional quality of objects hidden by their own shadow, and thereby contributes to conveying the total spatial effect of depicted relief.

15. Shadows in depressions.

One of the factors affecting variations in the illumination of surfaces is the multiple reflection of light, that has much to do with the nature of shadows in negative features of relief.

Light rays traveling in a relatively deep and narrow negative feature of relief are reflected many times against the walls of the depression and gradually lose their intensity as they become absorbed in this process. Light is at its lowest intensity near the bottom of such a depression. Fig. 11 is a diagrammatic representation of the path of light rays in a depression.

On the surface, directed light is operative as well: surface B is illuminated, while surface A is in shadow.

Thus, the overall illumination of such a feature results from the combined effect of directed, scattered, and repeatedly reflected light.

Light reflected by surfaces are subject to scattering on its path toward the eye of the hypothetical observer, and reaches the eye in weakened form. In this process, variations in the intensity of shadows are gradually obliterated. The deeper the depression, i.e. the longer the path traveled by reflected light to the eye of the observer, the more shadow differences are obliterated and the softer become shadow outlines.

As a result of the loss of light intensity in negative features of relief, shadows become more intense and darker.

The deepening of shadows inside depressions is easily noticeable on figures of marble or plaster because of their white surface which cause every gradation of shadow to be perceptible.

In depicting relief, this darkening of shadows is of great importance as a technique. Usually, this type of shadow is represented on the bottom of a negative feature, where it is most intense. Its nature varies with the shape and depth of the depression. For example, in ravines and fissures separating the lateral projections of a mountain chain, the appearance of shadows near the crest will differ from that of shadows at the foot of the chain. In the first instance, the shadow at the bottom of a ravine will be dark and have sharp edges, while in the second, the shadow will have indefinite outlines and fuzzy edges.

If the relief feature is broad in surface, shadows will not be greatly darkened. If the ravine is narrow, the shadow will be markedly more intense, particularly toward the bottom.

The atmospheric scattering of light likewise affects the darkening of shadows in negative features. The light reflected by the surfaces and traveling toward the eye of the observer from deeply receding ~~forms~~ features, will scatter to a greater degree than light reflected by features that are located near mountain crests and that are shallow. For this reason, it is legitimate to represent shadows as more diffuse and less contrasting

in the first case than in the second.

In representing negative features and darkening the shadows within them, due account must be taken of changes of direction, curvature, the width of the bottom, the grade of the slopes and the elevation of surrounding features, as well as of the direction of light. If the shadow is represented as a dark line or band, evenly extended along the bottom of the depression and fuzzy on the edges, the resulting image will appear unrealistic. If, on the other hand, the intensity of the shadow is varied to account for changes in illumination, and if the shadow occasionally merges with own shadow or grades into cast shadow or, on the contrary, assumes sharp outlines, the image will be realistic, and the shadow within the negative feature will be perceived as an integral part of the image.

It should be noted that artists often content themselves with representing only the projection of positive features, on the grounds that if the latter is acheived, negative features will thereby be conveyed. That, however, is not true. The salience of features is acheived by techniques emphasizing the areas near mountain crests and summits, and that do not serve to convey the recession of the lower portions of negative features. To acheive a complete three-dimensional effect, it is essential also to employ techniques aimed at conveying the recession of the lowermost portions of fissures and ravines. One of these techniques is the darkening of shadows in negative features.

10. Choosing light direction.

The creative activity of man, always manifested in an environment consisting of objects, requires that these be perceived distinctly through vision.

The distinct vision of objects hinges, to a considerable extent, on the presence of shadows, that always occur on illuminated objects. Cases of the total scattering of light, resulting in the absence of shadows, are relatively rare. Usually, of the many directions in which light travels, there is one that predominates. It is this main direction that determines the main features of the distribution of shadows on objects.

Depending on the light direction, variations occur in the outlines of shadows on objects, and this in turn affects the visual perception of these objects.

The most advantageous light direction for the perception of objects is one which causes distinctions on surfaces of objects that range from the lightest to the darkest tonalities and include all gradations of chiaroscuro. This may occur only when light direction does not coincide with the direction of the observer's line of sight. If the two coincide, the eye will see only illuminated and semi-illuminated surfaces. The darker shadows, even when present, will be hidden by the objects themselves and will not be visible. Reflected light will be absent.

The non-coincidence of the orientations of light and of the line of sight, i.e. side-lighting, allows the distinction of the full range of shadows that serves to define objects. Photographers, painters, decorators, stage lighters and architects make extensive use of side-lighting in their work. The observation of solid bodies in most branches of science and technology also involves the use of side-lighting.

The three-dimensional representation of relief also requires the use of a definite light direction, geared to the specific requirements of a map. Features of relief are conveyed on a map in orthogonal projection, and it is in this position that the reader of the map always sees them. This projection corresponds to a vertical line of sight. Therefore, to provide the most favorable conditions for the viewing of the features of relief represented, light direction should be other than vertical.

Light direction is defined in terms of its vertical component (the elevation of the light source) and its horizontal position (azimuth direction). In the vertical plane, various types of lighting are distinguished on the basis of their angle: vertical (elevation - 90°), horizontal (the light source is in the horizontal plane), and ~~oblique~~ lateral (the light source is in a position intermediate between the horizontal and the vertical).

In the horizontal plane, the direction of light rays may vary within the limits of a full circle. Usually,

light direction in the horizontal plane is defined in terms of cardinal directions, and various types of lighting are respectively termed northern, southern, northwestern, southeastern, etc.

17. The characteristics of vertical and ~~oblique~~ side lighting.

The most brightly lighted surfaces are those struck by vertical rays of light. As the angle of incidence is decreased, the illumination of surfaces decreases.

Fig. 12a shows that side-lighting results in the greatest illumination of surface A, which is struck by a light ray at a ~~xxxx~~ right angle or nearly so. Surface B is less intensely illuminated, and light strikes it an oblique angle. Surface C, inaccessible to rays of directed light, is totally obscured by shadow. Thus, oblique light causes both light and dark shadows, cast shadows, and other elements of chiaroscuro. The orientation of the line of sight does not coincide with light direction, and for this reason all the relations of light and shadow are accurately ~~xxxxxx~~perceived by the eye.

Fig. 12b makes it apparent that vertical lighting fails to cause any of the slopes to be struck by light rays at a right angle. Most of the surfaces, with the exception of horizontal ones, are only half-illuminated. There are very ~~xxxx~~ few surfaces hidden by total shadow. Among these should be included vertical slopes, tangential to the light rays, but they remain invisible to the eye, since the line of sight is also tangential to them. Vertical lighting causes opposite slopes of mountain ranges

to be illuminated equally, particularly if they are symmetric, instead of being divided into lighter and darker ones. Crests and summits do not serve as divides between lighted and shaded surfaces and, as a result, their projection is poorly appreciated.

All these factors do not favor the accurate perception of three-dimensional features, particularly of mountainous relief. In the representation of flat or slightly accidented relief, cut by ravines and characterized by flat or dome-shaped watersheds, vertical lighting is more effective. In such a case, the steep slopes of ravines and gullies are the least illuminated features. Dark shadows convey their complex network against the light background of shadows defining the gently slopes of dome-shaped hills.

If consistently used, side-lighting makes it possible to convey the features of any type of relief, including one that is flat or gently rolling. Fig. 12a makes it apparent that surface C, which represents a plain, receives less light than surface A, which is struck perpendicularly by light rays. It follows that, in representing relief, it will be necessary to represent all flat surfaces as in shadow, contrasting them with both shaded and lighted areas on the banks of rivers, hills and other features of moderate elevation, in accordance with their degree of illumination. The examination of photographs of relief models obtained with side-lighting always reveals that plains appear darker than slopes that face the light.

The three-dimensional effect of the shaded image is due, in large part, to the consistent use of side-lighting for all surfaces (Fig. 13).

However, maps frequently make use of side-lighting not for all surfaces, but only for features of mountain relief. The reason for this is that side-lighting requires that all flat expanses by covered with more or less intense shadow, and this background impairs the legibility of other features on the map.

Therefore, flat areas are often unshaded, while illuminated mountain slopes are rendered, in their lower portions, in light shadow, which is made to decrease and disappear with altitude (Fig. 14). This technique hinges on the unequal dispersion of reflected light reaching the eye from lower and upper portions of illuminated mountain slopes. Light reflected by lower portions has a greater distance to travel in reaching the eye than light reflected by upper portions, and is affected, to a greater degree, by the scattering medium of the atmosphere, which decreases the intensity of light. However, such an assumption requires that flat areas be also in shadow, as a result of light scattering, but this is not actually applied in practice. The use of side-lighting in practice allows a reasonably clear definition of features of mountain relief, but is not geared to the representation of flat relief, and has no way to compensate for loss of three-dimensionality caused

by the inconsistent use of side-lighting for all surfaces.

The integral application of side-lighting is exemplified on a number of maps, in particular some sheets of the American map of Alaska on the scale of 1: 250,000, 1952 edition.

Maps with background, though non-gypsometric coloration (political, economic, and others) may make consistent use of side-lighting, if the color background is used as a shadow covering flat surfaces.

Oblique or Side-lighting includes, as previously stated, lighting in which light direction is intermediate between the vertical and horizontal directions, i.e. when it varies within an angle of 90°. The actual range within which light direction may be varied is limited. In practice, the elevation of the light source rarely exceeds 30 to 40° in side-lighting. The use of an elevation of 30° for the light source in photographing relief models with equal horizontal and vertical scales yields satisfactory results.

Horizontal lighting is used on maps very rarely for the reason that the shadows cast by relief features are projected to infinity and obscure all projecting features situated at any distance from the light source. This type of lighting has been used on some maps of Switzerland, but the results have not been satisfactory. The entire relief situated to the south and southeast of the Pennine Alps was obscured, under conditions of

northwestern lighting, and lost its legibility.

In addition to vertical and side lighting, ~~cartography~~ cartography also recognizes oblique lighting, made to include all cases of side-lighting in which light rays strike at an angle, as well as mixed or multiple lighting, a category subsuming the simultaneous use of several light directions, such as vertical, lateral, and other types of light.

Oblique lighting is nothing but illumination from the side, i.e. side lighting, and differs only in name. Such a substitution of terms, that has become current among practitioners of side-lighting, seems unjustified.

Mixed lighting may be used with justification in photographing relief models so as to eliminate undesirable shadows. In drafting, mixed lighting is neither necessary nor advisable, since side lighting allows the use of all the needed elements of chiaroscuro to obtain a three-dimensional representation. At the same time, the estimation of all variations of light and shadow under combined lighting, such as joint side and vertical lighting, is a highly complex problem.

18. The characteristics of northwestern lighting.

In making use of side lighting, it is important to decide upon an orientation of light in the horizontal plane, i.e. on an azimuth direction of light, on the assumption that the hypothetical light source, like the sun, may vary not only in elevation, but also in

its position relative to the cardinal directions.

It would seem indicated in this connection to make use of ~~natural~~ conditions obtaining in nature, such as the position of the sun. During most of the day, the sun is situated in the southern half of the sky, and this would result in southeastern, southern, or southwestern light. However, in practice, orthography most frequently makes use of northwestern lighting.

How is this to be explained? The answer must be sought in the necessity of using the most habitual and convenient type of lighting for the perception of an image. The requirement stems from conditions governing our perceptions of real objects around us. In the course of any kind of work, such as writing or reading, we attempt to place ourselves in such a position as will allow light to fall on the object examined, and as will not cause the shadow of the hand to ~~shadow~~ fall on the sheet of paper or the book. The most convenient position is one in which light falls on the left and ~~from the front~~ in ~~front~~ front. People are accustomed to work in such a position, and to perceive, from such a vantage point, both the objects concerned in his work and other surrounding objects and shapes, outlined by their shadows. Any change in the direction of light such, as for example, a switch to lighting from the right or from the rear, will cause disturbance and discomfort.

Translated into cartographic terms, such lighting (from the left and right) becomes northwestern lighting, and it is this light direction that is most commonly used in maps. It is so habitual that if the representation is turned upside down, and if was originally executed in this type of lighting, the relief will be distorted: positive features will appear negative, and vice versa.

There have been made, and still are being made, attempts to use a light direction closer to that actually resulting from the sun's position, in particular a southern one. In particular, this type of lighting was used in a German air map on a scale of 1: 500,000. Its object was to allow the flier to compare the features of relief as they appeared on the map with those he observed under similar conditions of lighting. This aim was not acheived, and, at the same time, the appreciation of relief with southern lighting was found to be considerably impeded. The same requirements cannot be set for shadow outlines in a drawing and in the field. In a representation, shadows do not vary, while they are constantly changing their positions in reality. In the summer, the sun has an elevation of approximately 60° in the summer sky at our latitudes, while shadows on a map are assumed to be caused by a light source at an elevation of about 30°. Under such different lighting conditions,

similarities in the distribution of light and shadow should hardly be expected.

The use of northwestern lighting does not imply that the path of light rays is assumed to remain entirely constant all the time. The direction followed by light rays may vary, sometimes considerably, in accordance with the distribution of the features depicted and their relation to one another. These variations may at times be as large as 90° or even greater, though the light xxx should generally remain northwestern and affect the distribution of light and shadow correspondingly.

Variations in light direction in accordance with the position of relief features are evident in Fig. 13.

Chapter III

RELIEF MAPS AND MODELS AND THEIR USE IN RENDERING RELIEF BY MEANS OF SHADOWS

19. The use of relief maps and models.

Relief maps and models include three-dimensional representations of terrain, which can be prepared in a variety of manners. Models and maps are differently designated depending on their purpose. Relief map, terrain model, terrain mock-up, miniature polygon, sand box, topographic relief map are some of the many designations applied to such models and maps.

Of all existing types of representations of relief, models are the most effective visually. The visual

effectiveness of a model, which is that of a solid object, allows the visual appreciation of the three-dimensional quality of relief features not only by means of shadows, but also through the stereoscopic effect arising from the binocular vision.

Visual qualities are responsible for the ever increasing use of models in various branches of culture, science and technology. Models make it possible not only to obtain a comprehensive idea of the terrain, but also to effect calculations and to make accurate measurements of relief.

For educational purposes, relief models and maps are irreplaceable aids to study in a variety of fields. They make it possible to obtain some idea of the nature of terrain and the structure of relief both over large areas and in limited portions thereof, to gain some conception of the origin and geology of a given relief, of the distinctive features of local farming, such as drainage and irrigation, and areas subject to flooding. To a considerable degree, models are an aid to the study of cartographic techniques for conveying relief, such as the techniques of contouring, shadow representation, and ~~hypsometric~~ hypsometric coloration. Models also allow familiarization with instrumental and visual survey techniques, etc.

In institutions of higher learning that train specialists in various branches of the national economy, relief maps and models are highly valued as visual aids for education.

Relief models are even more essential in schools, where they allow a visually more effective explanation of the structure and characteristics of particular sections of terrain, as well as of entire countries, allow visual comparisons among the latter, and leave an indelible impression in the mind of the configuration of the area studied.

Yet, institutions of higher learning are still not supplied with the various models they need. Schools are even more poorly equipped in this respect.

Techniques used in practice in the preparation of models may be categorized as approximate or exact.

The process of preparing a model requires initially the construction of an armature for elevations, to allow the modelling over it of all inequalities on the surface of the model and to achieve control of the relations in height of various points on the surface of the model.

Approximate techniques, with the exception of the very simplest ones (which do not require any control over elevations whatsoever), involve the construction of the armature by means of vertical pegs of varying height or by means of vertical cross sections oriented along definite directions on the base of the model under preparation.

Exact techniques make use of an armature consisting of a set of plane surfaces, set one on the other to conform with variations in elevation. A series

of horizontal sur aces of predetermined thickness thus accurately reproduces the relief of the area and, at the same time, constitutes a ready-made ~~stepped~~ tiered model.

Approximate techniques require that the space between pegs or cross sections be filled with plastic material. All irregularities have to be filled in by eye. Exact techniques involve a stepped model which quite accurately reproduces the relief of the area, and require only the filling in of the concavities of the steps or the craving out of the solid angles formed by the same.

In recent years, modeling technology has advanced considerably. Highly efficient mechanical means for the preparation and reproduction of models have been devised, but they are not as yet widespread. Manual procedures still predominate. Mechanical procedures still contain a number of flaws that remain to be eliminated. For example, they do not allow the execution of one-piece models of large size. The model has to be made up of a series of blocks, which must be joined and adjusted to one another. In a number of cases, technology is responsible for lowering the accuracy of models to an appreciable extent, and the model may lose small-scale, though nonetheless important, features of relief, etc. These defects, that are susceptible of elimination, illustrate the need of developing the technology and training personnel for the processes of

of model production.

A photograph of a relief model whose surface has but one color, such as white, is called a photo-relief. A photo-relief, effectively conveying the orography of an area and the location of all features in it, may often be used as a map of the relief, if completed with a few additional entries.*

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*An example of this is to be seen in the "Photo-relief of the Caucasus" by G. Mets, on a scale of approximately 70 versts to the inch (1: 2,840,000), reproduced by means of photo-copy.

Another example may be found in a photo-relief of France, published in the atlas: Vivient de Saint Martin et Schrader, Atlas Universel de Geographie, Paris, 1925. It is also printed by means of the photo-copy process.

Modern reproduction techniques allow relief models to be used as originals for a representation by means of shadows in map making. Such techniques have already found their application in some maps**

** Relief models were used for the representation of relief by shadows on the German aerial map (1: 500,000), and for a similar representation on the American map of Alaska (1: 250,000) published in 1952.

If a relief model is intended for use as a relief map, it does not usually remain a single color, but is painted in some way and marked with the symbols appropriate to convey the contents of the map. The symbols themselves may be of the model type, i.e., in relief, of flat, i.e., drawn in paint and India ink by means of brush, drawing pen, curved knife [krivonozhka], quill, etc.

2C. Approximate techniques for the preparation of models.

We may cite as examples of the simplest models those made out of sand and used mainly in various branches of the armed services for training personnel. A box measuring approximately 2 by 3 meters is filled with sand or sand with a slight admixture of clay. the mixture is wetted down with water, and shaped to represent the terrain under discussion. As a result of the admixture of clay, the model does not crumble upon drying and yet may easily be destroyed if another model is to be prepared.

Mock-ups of buildings, bushes and trees may be set on the surface. Streams and roads may be represented by threads of varying colors, bodies of water are symbolized by pieces of glass or tinfoil, and various tactical signs are prepared out of wood, metal, rubber, or as drawing on cardboard. Depending on the subject under study and the problem, all these symbols may be moved around and changed. The relief may be warped or crumbled and then wetted again to prepare a different

type of terrain. In sand models, relief is shaped by eye, without the use of any reference points to determine elevation.

To prepare models of a more permanent nature, an armature for elevations is needed to control height relationships in the model.

The process of preparation for such models is as follows.

A map or a hand-drawn copy of one is, containing a flat representation of relief and elevations, is pasted on a piece of plywood or a wooden board. Metal stakes are then set on this foundation at key points (river valleys, crests, summits, bottoms of depressions, bases of mountains, watersheds) to serve as elevation guides. Relatively thick pieces of wire or nails may be used as stakes. The stakes are so set in the foundation as to protrude above it to a height equal to the elevation of the terrain at that particular point on a predetermined vertical scale. The space between the stakes is filled with plastic material: clay mixed with sand, plasticine, plaster, papier mache, etc. All inequalities between stakes are entered on the model by eye (Fig. 15).

Greater accuracy in rendering relief may be acheived by using an armature for elevations consisting of vertical cross sections, running through predetermined points or at right angles to one another. These cross sections, cut out of plywood or cardboard, are glued perpendicularly on the foundation or set into it. The intervals between the cross sections, like those between stakes, are filled in and shaped by eye (Fig. 16).

The shaping of the surface is done manually. However, there are many details of relief that must be shown and that cannot very well be modeled by hand. For rendering such details, use is made of wooden spatulas, sticks and wooden pins that allow the modelling of the smallest cavities and the smoothing of the surface of the model.

In modeling superficial inequalities, it is important to make sure that the ends of stakes or ribs of cross sections dom not protrude above the surface of the model and, at the same time, that they are not buried at any depth. The surface of the model must coincide with the tips of the stakes or the edges of the cross sections.

21. Exact techniques for the preparation of models.

Three-dimensional relief is most accurately shaped in accordance with contours. Contours make it possible to prepare a solid model without recourse to the visual interpolation of minor inequalities. Modeling in accordance with contour lines in practice consists of obtaining plane surfaces outlined by contour lines and stacking them on one over the other. The thickness of each surface depends on the interval and the vertical scale used.

The preparation of the model requires a foundation in the form of a wooden board or a piece of plywood. A map in which relief is expressed by means of contour lines is glued on this base. Then the thickness of each

horizontal layer representing one contour interval is determined in accordance with a given vertical scale, and the number of these layers is counted. Such layers may be made from of cardboard or from plywood of the required thickness. The number of layers used equals the number of contour lines required to express the relief represented. On each sheet of plywood or cardboard, a drawing is made of the contour which will delimit that particular layer, as well as a drawing of the next inner contour where the adjoining upper layer is to fit. Each layer also bears a coordinate grid (of rectangular or geographic coordinates) to guide the fitting of the layers together. Contours and grid may be marked in a variety of ways: by gluing map sheets bearing printed contour lines and grids onto the plywood or cardboard; by printing the contours and coordinate grid directly on the cardboard; or by drawing in these elements by hand.

A layer delimited by a specific contour line is cut out of each plywood or cardboard sheet.

The layers may be cut out with a knife, scissors, or a fret saw.

A mechanical fret saw may also be used, whose blade, set in motion vertically by an electric motor, is fixed on a lathe, while the sheet of plywood bearing the contour line is moved under it. A saw of this type expedites greatly the process of cutting out the layers.

The excised flat layers are then layed in sequence in order of elevation over the foundation bearing the glued-on map. The layers are correctly placed by reference to countour lines and the coordinate grid. The layers are joined to the foundation and to each other through gluing with wood glue, rubber cement, or some other adhesive, or may if necessary, be hammered on with nails. The result is a tiered model (fig. 17).

Subsequent processing of the model consists in evening out the stepped surface by filling in the dents between the protruding ledges or the carving out of the tiers themselves. In filling the dents, some plastic material, such as a mixture of plaster and clay, plaster, papier mache, a mixture of chalk and glue, etc., is used. The cutting way of the tiers is done with a knife and a scalpel.

22. Mechanical techniques for the preparation of tiered models.

Manual means of cutting out layers and preparing tiered models involve a considerable expenditure of time and are notable for their inefficiency.

In the last decade, a number of countries have begun to make use of mechanical laths that make possible the preparation of tiered models out of a variety of materials with much greater rapidity than is possible by hand. Except for some technical details, the earlier [illegible] of [illegible] not differ fundamentally from current ones.

One such machine is the three- imensional panto-raph, which is essentially a copy milling machine (Fig. 18). The machine consists of two supporting surfaces: one is anchored in one place, the other moves ertically. A pantograph, operating in a 1:1 relation, is fixed above the supporting surfaces. One of its ends is a tracing point, the other a cutter. The first supporting surface bears a contour map, the other a plate of lead, duralumin, plaster and paraffin, plastic or other material. As the tracing point follows a contour line, the cutter repeats its motion exactly and cuts out a groove of predetermined depth in the plate, which reproduces the pattern of the contour. The entire part of the layer situated outside of the contour is removed by a larger cutter.

The cutting begins with the highest contour line. Following the cutting of the first contour and the removal of the layer lying outside of the limits of the contour, the surface bearing the plate is raised to a predetermined height, and the following contour is cut. The process is repeated until the lowest contour line has been cut. If bodies of water of lower elevation than the lowest contour are to be represented, a cut is made to follow the shoreline.

The use of a copy milling machine has made it possible to greatly reduce the time required for the preparation of a tiered model.

Such machines have been used in France (by the firm made by the Hure company) and in Germany (by the Deckel company). A machine patterned after the Deckel model was built at the "Hammer and Sickle" plant in the USSR in the 1930ies.

Lately, a three-dimensional pantograph has been placed in operation by the K. Wenschow concern (German Federated Republic).

The Cartographic department of the U.S. Army also uses a pantograph of German design, with some additional improvements. The solid plate from which the model is prepared is replaced by a laminated plastic block. The thickness of each layer equals the elevation of one contour interval on a predetermined vertical scale. The layers are glued and pressed together. The motion of the tracer causes the plastic to be cut by the milling cutter. After the tracing is completed, the entire portion of the layer lying outside of the contour line is removed by hand. As the cutter is progressively lowered, the outer portions are removed in turn, and the result is a tiered model. In additional, human error on the part of the operator is obviated in tracing the contour lines. The tracing point is replaced by a phonograph stylus that follows not a contour drawn on a map, but a grooved set of deeply etched or engraved contours on a glass or metal plate. The stylus follows the grooved contour line without

having any leeway for lateral motion, and this excludes the possibility of human error resulting from the tracing of the contour with a blunt point.

In 1939, the Soviet engineer A.A. Magaznov devised a metal-stamping process for the preparation and reproduction of relief maps, consisting in the following. A thin sheet of nickel-plated copper (0.1 mm thick) was imparted a complete contour representation on both faces by the chromo-albumin process. Further processing led to the removal of the nickel along the contour lines. The contours thus appear as yellow lines on a white background. The sheet is then placed on a rubber plate, and a special engraving tool is used, alternately from both sides, to stamp out the metal along the contour lines to produce a tier-like protrusion. Successive stamping along each contour line produces a relief model.

A negative form is then obtained through plating or casting, and it, in turn, yields a positive cast out of papier mache. The positive and negative forms are then placed together in a press so that one fits in the other. Special reference markings make it possible to place between them a moistened map sheet which is converted, in the press, into a relief map.

A relief map of the USSR on a scale of 1:22,000,000 has been prepared experimentally by this process. The resulting maps were found to be inaccurate, a circumstance to be explained by the use of manual processes and inaccuracies of execution. A.A. Magaznov was killed in the front lines during World War II. No further

xxxx work was done on this project.

In 1944-1947, a metal stamping process, similar in principle to that of A.A. Magaznov and technically superior improved, was put to use in the United States. A machine has been designed for the mechanical preparation of a metal model. The machine is called a reliefograph (fig. 19). The reliefograph consists of a massive tabular part, over which is mounted a pulsating hammer on a movable arm, with a rubber tip. The hammer is mobile in all three directions. A rubber plate is placed on the tabular part. The distance between the hammer and the plate is regulated in accordance with the vertical scale employed. A sheet of soft aluminum about 1 mm in thickness on which the contour lines have been printed is secured in a frame by means of clamps that keep the sheet in place, in a position parallel to that of the surface of the tabular part. The sheet is stretched tightly to allow the stamping of relief on it. The tabular part is placed under the sheet in such a manner that its rubber covering is in contact with the sheet of aluminum. The frame is moved upward and downward by means of a manually controlled wheel. A foot pedal and a rheostat control the vibration of the hammer. The tabular portion and the vibrating hammer are lowered for the stamping of each contour interval to a depth corresponding to its relative elevation for the vertical scale selected.

Pressing begins with the lower contours, and proceeds to the higher ones, but the resulting model is negative. A positive model is obtained by filling the inside of the model with paraffin or some other rapidly drying compound. In this process, pegs are set at definite points enclosed by contour lines to provide ~~xxxxxx~~ openings for the removal of air from air pockets.

All the parts and accessories of this machine are mounted on a solid frame of cast steel for use in mobile military units engaged in the production of maps.

At present, the metal stamping process has given way, in the US, to the execution of models by cutting.

A cutting machine designed in Italy has a fixed marker, under which a map sheet is placed on a spool, and a fixed milling cutter. A ~~xxxx~~ plastic plate is laid on a table under the cutter. A special set of controls guides the contour line under the marker. The model under the mill cutter is accordingly set in motion, and the contour is cut. This machine is less practical, though no less bulky, that the German machine.

Soviet cartography has developed a number of processes and techniques for the preparation of relief models. In particular, G.N. Petrov has proposed a machine of original design, which allows the ~~xxxx~~ mechanical preparation of relief models out of material

contained in a specially designed pack. The tracing of a contour on a map by means of a tracing point results in a negative tiered model which is impressed on the surface of the pack, which is then used to cast a positive out of plaster. The tiers may be smoothed out by hand on the plaster cast. Following the casting of the plaster model and the smoothing of the material, the pack may be re-used to model relief.

The efficiency of the preparation of models by various means may be measured as follows.

The preparation of a model of one quadrangle of a large scale map requires:

110 hours, by the process of stacking hand-cut cardboard layers;

78 hours, by the process of stacking machine-cut cardboard layers;

16 hours, by the process of machine-stamping (casting of plaster model not included).

It is important to note that the accuracy with which contours are stamped or cut is an important criterion in evaluating mechanical means of model preparation. Copy milling machines are the most accurate, since they may operate with mill cutters no larger than 0.2 mm in diameter. This allows the reproduction of all minor curves and closely spaced contours.

23. Surface processing and accuracy control of models.

The tiered surface of the model may be smoothed either by filling in the grooves between the tiers or

by cutting away their projections. Spatulas, rods, pins, etc., may be used in filling in grooves with plaster. A convenient tool for carving away the projections is scalpel with a sharply curved blade. It is advisable to proceed to the smoothing of the model before it is entirely dry.

The accuracy of a tiered or smoothed model is controlled by means of a "shadow projector" (Fig. 20). A shadow projector consists of a lens projecting a shaft of parallel light rays, a point source of light (for example, a multiplex projector bulb) and a support for the model, above which is placed a positive image of the contour lines on a transparent plate (camera film).

The light rays, emanating from the lens, are in the form of a parallel beam. The shadows of the contours cast on the model should therefore coincide with the tiers of the model. When a discrepancy is discovered, parts of the model are enlarged or cut away. The dimensions of the shadow image is determined by that of the lens; the image cannot exceed the edges of the lens. Therefore, the checking and correction of a large model requires the use of a lens of equally large size, allowing the projection of contours over the entire model. Otherwise, checking must be done in several stages.

The shadows of the contours also provide an opportunity for filling in on the model certain

indispensable details that may not always be transmitted in the process of model preparation. Such are gullies, cut banks, rocky crests, fills, mounds, etc.

In improving the accuracy and checking a relief model, it is important to generalize the details that are being incised or applied. It should be remembered that details are essential in a representation: they serve to characterize relief just as much as larger features. However, their overabundance may obscure the larger features. Details should be shown to the extent that they aid in conveying the nature and characteristics of the relief.

Experience, skill and artistic sense are important in modeling details, since they aid in acheiving an expressive and realistic rendition of relief.

For checking a smoothed model, the tiered model is colored in some dark shade (e.g. black, or brown). When the projections are cut away or the grooves filled in with white plaster, dark lines should show up in originally projecting or grooved parts, and these should coincide with the contour line shadows obtained by means of the shadow projector.

The surface of a smoothed model usually has rough spots and cracks and requires spackling. Spackling is done with a mixture of chalk with wood or paper glue, which is then smoothed with sand-paper without, however, destroying any details.

Further processing varies with the purpose of

the model. If the model is intended for use as a relief map, its entire contents needs to be entered by means of coloring, drawing or the use of solid symbols, or any combination thereof.

When the model is to serve as an original for the production of copies, contents is not entered. For obtaining a photorelief, the model should be coated with a suitable compound of definite color.

Contents is entered on relief maps in a variety of ways. For example, cultivated land, pastures and settlements are represented on large scale maps by means of various colors. The method of pasting aerial photographs on the models has also been used. To this effect, an aerial mosaic was broken up into triangles, of which two angles were situated on a contour interval, while a third could be easily located both on the map and on the photograph. These triangles were wetted and pasted on the model, and the latter was then tinted in various shades, for example with printer's inks. The colors were applied with tampons. When it was found necessary to obtain sharp boundaries between background colors, stencils made of stiff paper were used, or else plain sheets of paper to shield areas which were not be colored. The details of the aerial photographs would remain clearly visible through the transparent color layer. Colors help considerably in contrasting large areas which may not be picked out easily on black and white photographs.

Small-scale relief maps are most commonly tinted according to the gypsometric scale. Hues are selected in accordance with the type of relief present.

Solid symbols are often used on relief maps to indicate existing structures, plant cover, roads and other elements.

Solid symbols may be prepared from the most varied materials. Structures may be represented in wood, linoleum, rubber. Trees, shrubs and forests may be shown by means of rubber sponge, moss or saw dust. Railroads may be indicated with metal wire. Water bodies are depicted with celluloid, vinyl or glass surfaces, colored on their obverse faces in a light blue or other color. American relief maps prepared during World War II had symbols for plant cover, in particular green hedges, imparted by means of a syringe, which ejected a coloring substance.

Labels may be applied in a number of ways: they may be lettered by hand in ink, water colors or nitro paint, or applied in the form of labels printed on ordinary or waxed paper. Decals may also be used.

The pasting of printed labels yields the most unsatisfactory results, because the labels standing out because of their whiteness, and requiring tinting to conform with the color of their background. Labels printed on transparent material (tracing paper or waxed paper) do not stand out

as much against the background of the map, but have to be pasted on securely, so that the entire surface of the label is contact with the surface of the map. Decals yield good results, but technical conditions do not always allow their use.

In finishing a relief map, it should be kept in mind that it is intended to convey the relief of the earth's surface in a visually effective manner. This purposes implies, in turn, a visually effective rendition of other elements in the map. This explains the use of solid symbols and natural colors.

In coloring a map and placing symbols it is important that these fit the purpose and scale of the map. Symbols may be magnified somewhat in relation to the map scale, as long as this magnification is not very obvious and does not prevent the symbols from appearing realistic. Colors cannot be too variegated or too bright, and must combine and blend well with one another.

If all these conditions are observed, a map may be made to produce the effect an exact replica of the terrain on a smaller scale. The artificial nature of the model will be forgotten, and the map will acheive thereby a maximum of visual effectiveness and comprehensibility.

24. The reproduction of relief maps.

Processes for reproducing relief maps and models, like the processes for producing them originally,

have benefited recently from technical improvements that allow much more rapid duplication than had been possible previously. However, new techniques have not yet gained wide currency. Manual craft processes still predominate.

The manual duplication of models is done as follows.

The model to be copied is coated with a thin layer of a solution of vaseline in kerosene, so that the projected negative form does not stick to the surface of the original. The model is placed in a box, whose sides exceed the height of the model by 1 or 2 cm. A solution of plaster or alabaster is poured into the box so that it fills it to the brim and covers all inequalities of the model's surface. After the plaster has dried completely (in 3 to 4 hours), the box turned over, and the mould taken out. The surface of the mould is then coated once or twice with waterproof lacquer, to make it impervious to water.

The mold, also coated with vaseline, may then be used to obtain positive copies of the model by being filled with a solution of plaster, papier mache, or sheets of paper soaked in a thin solution of starch or paper glue. In preparing the duplicate, the plaster or papier mache is distributed evenly throughout the mold and is pressed into all of its cavities. The paper for the first layers should have little glue in it (filter paper, wrapping paper or newsprint

may be used), and is later replaceable by thicker paper. The paper is first soaked and partially dried, to ensure a closer fit in the mold. The paper is torn into small pieces, which are laid out over the mold and pressed by hand, stamped with a stiff brush and poked into all the recesses of the mold by means of sticks. The pressing of the layers of paper into the mold, particularly the first layers, determines the accuracy of the copy. The first one or two layers of paper should be laid without being coated with glue. The copy must be of adequate sturdiness, and the total thickness of the layers of paper should reach about 1.5 mm.

Along the edges of the mold, the layers of paper are folded out to form a fringe.

After the casting has been completed and the model has dried, it is taken out, set on a wooden support, and achored by gluing the fringe to the support. Cracks anf fissures are then spackled, and the model set on a dais.

The mounted model is then colored and provided with all the elements of contents it needs.

Among the techniques for reproducing copies of relief maps, mention should be made of stamping, in use as early as the XIXth century. The relief appearing on a map, printed on cardboard or thick paper, was pressed between a positive and a negative die, fitting one into the other. This process was used in publishing school maps, as well as specialized and topographic ones,

both in Russia and abroad. The process ensured an accuracy of fit between the map and the mold within limits of 1 to 2 mm, which is plainly inadequate for maps with relief of any complexity.

Lately, the process has enjoyed some currency in France. The manufacture of copies involves the printing of the map on ~~xxxinxxxxxkxx~~ glue-soaked filter paper. A hydraulic press exerting a pressure of 100 atmospheres presses the map into form made of magnesium oxychloride cement or coated with metallic powder.

In the United States, copies of relief models are made of rubber. A plaster mold, made from the original model, is sprinkled with powdered mica or talcum, to prevent the adhesion of the rubber to the mold. A mixture of liquid rubber and filler (a chalk paste) in water to which concentrated ammonia is added is applied to the surface of the negative with a brush or by means of a special atomizer. The mixture is applied in several successive layers. In applying the first layers, aqueous solutions of coloring agents are added to the mixture to color the copy in various colors. Mountains are colored dark brown, beaches are light brown, bodies of water are blue, wooded areas are green, and buildings are represented in white. Each layer of rubber applied is sprinkled with a solution of acetic or citric acid, which speeds up the setting of the rubber. Over the damp

layers of rubber, fragments of cloth soaked in the same rubber mixture are applied. The number of cloth layers depends on the rigidity required of the copy.

For an hour, the copy is dried at a temperature of about 60° C. It is then vulcanized at a temperature of 80 to 120° C and stripped from the mold. The entire process of duplication takes about 8 hours. The final coloring of the copy is done by hand, and various elements are then entered on it. Rubber copies of relief models are used by the United States Navy for training purposes.

The most perfect of the processes for the duplication of relief maps is the vacuum method.

A multicolored print of the map is made on a white sheet of vinylite. A negative plaster mold is set in a vacuum frame, and is provided with apertures for pumping out the air. The mold is covered with the map printed on vinylite and is fitted to it by the use of certain reference markers. The map is hermetically attached to the borders of the model and is covered with a lid, equipped with a water heater. The increase in temperature causes the vinylite sheet to ~~xxit~~ soften and to adhere closely to the surface of the mold as the air is pumped out. When cold water is ~~isi~~ passed through the tubing of the vacuum frame, the vinylite cools and hardens once again.

A recently designed frame dispenses with the 'id. There is a frame, to which a sheet of vinylite and a plaster mold are pressed. Instead of a hot water system, a radiant heater causes the sheet to soften. Not being sealed in, it allows the observation of the molding process. The time needed to produce a relief map is 2 to 4 minutes.

The white vinylite sheets have been replaced by sheets of transparent material. A mirror image of the map is printed on the lower side of the sheet. The accuracy of fit between the mold and the map is of ± 0.5 mm. 50 copies may be made within the space of an hour.

The overall process, in the United States, including the cutting of a model out of a laminated block, the printing of t e map on vinylite sheets and the pressing of 50 copies takes 48 to 72 hours. The equipment occupies a floor space of 45 sq. m.

In the USSR, a vacuum procedure is used in which a sheet of vinyl is applied to the mold in a pre-heated and pre-softened state. This allows a considerable reduction of the space between the mold and the vinyl sheet, and the air may be pumped out rapidly, without the formation of fissures in the vinyl.

25. Choosing a vertical scale for the relief map.

The vertical scale is intimately dependent on the horizontal scale. In selecting a vertical scale, a practical relation of the horizontal scale to the

vertical scale must be worked out. If the relation equals 1, the vertical scale equals the horizontal, and the elevation of the relief is modeled on the scale of the map.

However, elevation is so minute, in actuality, compared to the other two dimensions of the map, that altitude must be exaggerated to allow the visual appreciation of relief, and the vertical scale must be greater than the horizontal.

The relation of the horizontal scale to the vertical may vary within broad limits, from 1 to 1/20, but rarely exceeds these.

The choice of vertical scale is determined by the use for which the relief map or model is intended, and the nature of the relief represented.

For example, a model used as a visual aid in an educational institution or in analyzing a military operation has as its aim the visual rendition of all specific features of relief. This requires a considerable exaggeration of the relief in height, and allows for a variation in the relation of the horizontal scale to the vertical within the limits of 1/5 to 1/15. If the purpose of the model is different (for example, if it is to be used to obtain an image with shadows), the relation of the scales will likewise differ. A representation by means of shadows requires a mimimum number of dark shadows obscuring depressions, of the kind that are inevitable when the elevation of the relief is greatly exaggerated. To obtain an image

with shadows, and in accordance with the nature of the relief, the relation of scales should be close to 1 or to 1/2 for a given type of lighting.

A weakly accidented relief, containing only moderate eminences, requires a horizontal scale considerably smaller than the vertical, and their relation should equal approximately 1/5 to 1/10. A relief with considerable differences of elevation (a mountainous relief) requires relation of the order of 1/2 to 1/5. Thus, if the same model is to represent differing types of relief, the distinctive features of each should be taken into account in choosing a vertical scale.

In practice, attempts have been made to prepare models with a variable scale. For example, a model representing simultaneously flat, hilly and mountainous relief would vary in ~~xxxxx~~ vertical scale, the latter being increased in passing from mountainous to low areas. While the relation of scales would be of 1/7 for low areas, a 1/5 relation would be adopted for areas of medium relief, while a relation of 1/2 would be applied in areas of high mountains. The relations may also be varied in accordance with a somewhat different principle. Scale variations may be tied to areas of specific elevation. Thus, a relation of 1/7 is used in the 0-500 m elevation zone, and is successively increased to 1/5 for the 500 - 1500 m zone, to 1/3 for the zone above that,

then to 1/2 and so forth. The higher the elevation, the smaller the vertical scale becomes.

The use of a variable scale, a practice that still requires experimental and practical testing, may be justified if the model is not used for measurements. Measurements in a context of varying scales is made complex by the necessity of adjusting the results to a single scale. This becomes particularly difficult of a given measurement involves two different elevation zones, that are rendered in two different vertical scales.

In choosing a vertical scale, it may be very helpful to construct profiles which will allow an estimate of how realistic the relief will appear in the model. In doing this, it is advisable to draw up several profiles, at different vertical scales, for the same areas, and then compare them visually.

26. The use of relief models to obtain shadow representations of relief.

Basically, the process of obtaining a shadow representation consists of photographing a relief model, and the subsequent processing of the obtained photographic image.

A photographic image may be used in several different ways.

One possibility is to have the photograph of the relief model (the photo-relief) serve as the central element of the cartographic representation, while other elements are given relatively little emphasis

and play a subordinate role.

Another alternative is to print the photograph of the relief model, after appropriate processing, on a map, which contains a complete inventory of other features.

The initial stage in both cases is the same. It consists in obtaining a photorelief (Fig. 21). The latter's subsequent processing and color finishing, however will differ.

To obtain a photorelief, the relation of the scales used in preparing the model should be equal or close to 1, to avoid creating deep and long shadows. The entire surface of the model should be painted one color, such as white.* After painting, the surface should have a mat finish and not reflect highlights when illuminated. White gouache may be used in painting, but if the paint layers are laid on with a brush, highlights are unavoidable. The best results are achieved with the end of a horsehair brush (by "stamping") or with a spray-gun that makes it possible to obtain a dull surface.

K. Wenschow's concern (Federated German Republic) coats its models with aluminum paint before photographing them. This makes it possible to obtain very sharp shadows

* Cases in which the model is not of uniform color will be examined subsequently.

in the photograph. The structure of the aluminum particles must be such as to create a mat surface.

In preparing a photorelief which is not intended for printing into a map, it is necessary to enter, on the surface of the relief and by reference to relief features, a detailed representation of drainage, principal roads, population centers and labels, and to draft in the framing and title of the map.

The photorelief thus obtained is then completed by entering other features, represented by various colors: bodies of water, in blue; wooded areas in green; roads in red, and so on.

If the photorelief is being prepared for printing in on a map as a shadow representation, the contents of the map is not entered on the model.

The reproduction of all shadow gradations in a photorelief requires high grade printing. Good results may be obtained by the phototype process, which makes it possible to obtain an image with little loss of shadows.

Photographing a model requires the use of a special lighting system, allowing the most favorable light direction.

In the experimental photography of models, it has been customary to use the bilateral lighting arrangement commonly employed in photography. When photographing a model, one of the bulbs is turned off, while the other is so placed as to cast light on the model from the side at a definite angle and from a

definite distance. The angle and distance are determined by trial and error, to avoid the creation of unduly long shadows, and to have the light distributed uniformly over the entire model.

When the relation of scales equals 1, such a lighting arrangement makes it possible to obtain a photorelief in which shadows serve adequately to express relief, but which also has definite faults: all shadows appear unduly sharp, own shadows lack half-tone distinctions within them and obscure the major features of relief. This is to be explained by the fact that such a set up provides only direct light, the effects of reflected and scattered light being absent.

The K. Wenschow concern (German Federated Republic), which manufactures relief models and photoreliefs, employs a special lighting arrangement, consisting of several light sources.

The first source illuminates the model with oblique light from the side, AA (Fig. 22:a). In depressions situated below line aa (Fig. 22:b). this creates deep shadows, which preclude the reading of relief structure. A second light source, also providing an oblique beam BB, weakens these shadows, without eliminating them entirely. Dark shadows remain in deep fissures and depressions (cc). For this reason, a third, vertical light direction D is used, to illuminate the darker areas.

The second light source is mobile. Its function

is to correct the defects caused by the other two and to create shadows serving to emphasize specific features. It plays a highly important role in acheiving a plastic effect for all the individual components of the image. The intensity of the light may be varied. If various portions of the model require extensive changes in light direction (BB), these portions are photographed separately and then fitted together.

All the light sources used in illuminating the model are in the form not of point sources, i.e. one bulb, but are constituted by sets of bulbs. Thus, for example, in lighting the model from above, light bulbs may be mounted in a ring around the lens of the camera, shielded to prevent reflections. The lateral light source may be mounted on a rectilinear rod, while the corrective light source may also be in the form of a ring, in which not all lamps are lighted, but only those required for the correction of specific defects.

Different lighting arrangements are also possible.

Except for its central part, the photograph of a relief model exhibits a shift of various points of the image outward toward the margins of the photograph. The higher the relief features in the model and the closer they are to its edges, the greater the outward shift. This shift is to be explained by the path of light rays through camera lenses according to the laws

of central projection. This results in the non-coincidence of the shadow image and the representation of relief by contour lines, which is drawn in an orthogonal projection.

To ~~xxxxxxxxxx~~ preclude this type of distortion or, at least, to reduce it to a minimum, the K. Wenschow company (German Federated Republic) uses a camera with a lens of long focal length. The camera is in the form of a tube, and has a focal length of 22. 5 m. The lens diameter is 38 cm. The power of the light source is 30 kilowatts. The use of this type of lens prevented the distortion of the relief image on its peripheries. However, the installation is altogether too bulky.

The optical system used by the United States Army cartographic service includes a spherical mirror measuring about 85 cm, with a focal length of 4.6 m, and a Tessar lens of 30 cm focal length. Objects reflected in the mirror are photographed through the Tessar lens. Changes in the distance between the lens, the mirror and the model modify the projection of the resulting image, which may be changed from central to parallel and inverted ~~parallel~~ central.

If an arrangement of this type is used in perspective photography of objects equal in size situated at different distances, central projection will cause closer objects to appear larger than more distant ones.

A parallel projection makes it possible to have all objects appear the same size in the photograph. An inverted central projection causes more distant objects to appear larger than closer ones.

Fig. 23 shows the photograph of a model taken in central projection. The lines of the coordinate grid, drawn on the model as projections of straight lines, appear as broken and curved lines as a result of the lateral distortion of the relief. Fig. 24 shows the photograph of a model in parallel projection, in which all the lines of the coordinate grid occur as straight lines, since no lateral distortion of the relief occurs.

The optical system described allows obtaining photographic images in orthogonal projection, coinciding in all points with the contour-line representation of the same relief.

This system may also be used in checking a tiered relief model. In this case, a contour-line representation is projected in parallel projection onto the model. All contours should coincide with the tiers of the model. Deviations of the tiers from the contours are corrected either by removing excess material, or adding it on where needed. However, the shadow projector previously described is more convenient for this kind of checking.

The model may be variously colored for the purpose of obtaining a photorelief. The surface of

the model may be unfformly colored white or some other color. In other cases, the coloration of the model may be varied according to definite rules, allowing the rendering, in addition to light and shadow distributions, of other characteristics of relief.

Certain concerns in the Federated German Republic color models by immersion in a coloring agent, out of which the model is withdrawn gradually, thus being dyed according to the principle of "the higher the elevation, the darker the color" or "the higher the elevation, the lighter the color". In this manner, it is possible to color flat portions of the model and provide gradual transitions to more mountainous portions, which are colored differently. The model may also be colored by means of a spray gun, an atomizer, or a brush. In using a spray gun, it is possible to vary the coloration of model surfaces in accordance with their orientation in relation to the cardinal directions. For example, northwestern slopes may be colored one way, southeastern ones another. Color separation in the photograph is obtained through the use of light filters. This method of coloring allows to obtain a generalized shadow pattern on the photograph.

Thus, the varied coloration of models makes it possible to acheive a photorelief with not only a shadow representation, but also other characteristics

of relief: hypsometric coloration, contrast between mountainous and flat areas, etc.

Procedures for the utilization of relief models and photoreliefs for the representation of relief by means of shadows cannot, as yet, be considered adequately developed, particularly for multiple-sheet and large size maps. The matching of the shadow pattern on adjoining sheets, the problems of coordinating the shadow pattern with the coloration of elevation zones, the elimination of distortions occuring as a result of the photographic process, and the standardization of processes entering into the overall process of obtaining a photorelief and a shadow image, all need additional experimental working over, and integration into a technological procedure incorporating all processes.

The realization of a high-grade photorelief is a first step. It is not rare that a photographic image, expressively and effectively conveying relief, loses its qualities when printed, becomes distorted, and is changed from a contrasting image exhibiting all gradations of the shadow scale into a dull grey, drab, inexpressive image as a printed map.

Distortions and losses within the photorelief are determined, in large measure, by the very nature of the use of a grating printing, which breaks down a continuous succession of half-tones into minute discrete elements.

A photograph also undergoes substantial changes

when it is converted from a black-and-white image to a colored one on the printed map. Any chromatic tone is characterized by a smaller differential of brightness and less intensity than an achromatic tone. As a result the effect of a gradation of shadows is always more fully transmitted in an achromatic, than in a chromatic (single) tone.

In order to preserve the effectiveness of the shadow image, a second set of contrasting half-tone originals is prepared and, in the printing process, a whole series of color tones is introduce to heighten three-dimensional quality.

The merits and suitability of a photorelief for printing purposes must be determined visually. The density of the photograph, in whole and in each of its parts, may be measured, but this does not yield an adequate criterion of the quality of the photorelief, since it serves only to evaluate contrast, and the relation of intensities between various parts of the photographic image. The basic concern, however, must be to evaluate the three-dimensional effectiveness of the image and to determine, accordingly, what editional retouching work needs to be done on the image and in preparing additional originals.

The realization of a shadow representation of relief through the use of models is not limited to obtaining a photorelief and reproducing it.

The processing of the surface of the model obtained requires considerable experience in the

shaping of details that serve to characterize a given type of relief, and some knowledge in the field of geomorphology. The execution and verification of work needed to preserve the effectiveness of the image may be carried out in cooperation with qualified cartographic artists. In this connection, it is important to be able to tell, upon brief and preliminary inspection, what additional processing and what kind of additional originals will be needed.

The use of models and photoreliefs for the purpose of obtaining shadow images of relief is efficient, and allows to cut down on manual work. The use of models in production requires an adequate technology, certain indispensable technical equipment, and the participation of a qualified cartographic artist, capable of visually evaluating the merits of a photo-relief, and of determining the extent of additional manual work required, and of executing these, whether they involve retouching the photorelief or the preparation of a second original.

Chapter IV

THE FUNDAMENTALS OF COLOR UTILIZATION IN THE PLASTIC REPRESENTATION OF RELIEF.

27. Color variations as observed in nature.

A representation of relief by means of shadows may involve the use of various types of colors: achromatic (from black through grey to white), single chromatic, or combined colors. In each case, the

three-dimensional effectiveness and readability of the depicted relief will vary.

An achromatic representation may be highly effective in a three-dimensional way if shadows vary in tonality and range from light to very dark. However, in this type of representation, the overall background is relatively dark, and the linear elements and labels suffer from impaired legibility. For this reason, achromatic representations are rarely used in published maps.

The use of one chromatic tone, such as brown, which is less intense than black, makes it possible to obtain a lighter background, against which linear elements will be more easily seen. Yet, it will be precisely as a result of the lesser intensity of the color used, causing the absence of deep shadows in areas where they are needed, that will decrease substantially the effectiveness of the shadow representation. Furthermore, linear elements and inscriptions covering parts of the image will impair its legibility. The intensification of shadows required for visual effectiveness will again lead to a dark backrgound, as in the case of an achromatic image.

The situation is different as regards a shadow representation rendered through various color combinations. The use of several colors allows not only a more effective three-dimensional image than can be obtained in a monochrome image, but at the same time makes it possible to preserve a light background, against which linear

elements and inscriptions will be read much more easily than on a monochrome shadow representation.

The color variations used in a three-dimensional image are not determined accidentally. They conform to the laws of color variation in objects observed under natural conditions.

The apparent colors of objects around us change in accordance with their distance from us. For example, at close range, the color of a forest appears as a combination of various shades of green. As distance is increased, the green hues of the forest are seen through atmospheric haze, and acquire a light bluish or bluish purple quality. This phenomenon, called aerial perspective, is regular and ordered in nature. The farther objects are situated, the more they are screened by a bluish haze.

People observe color variation in the course of their daily activities. The regularity and constancy of this phenomenon are such as to cause an association between the distance of objects and variations in their color. As a result, color hues containing varying admixtures of the hue of atmospheric haze, are in themselves perceived as removed to varying degrees from the observer. This peculiarity of color perception is used extensively by painters in their works to convey distance in landscapes. Such is the importance of these color combinations that if a painting fails to reflect the

presence of atmospheric haze, distance is not perceived by the viewer.

The principles of aerial perspective are also used in cartography, as aids in conveying depth in the representation of relief.

The color combinations used in representing space and mass are derived from color variations occuring under natural conditions as light rays travel through the atmosphere. The imitation of these conditions allows the creation of an image which is three-dimensionally effective, and the conveying of space and solid forms in that image.

28. How light is affected by the atmosphere.

As we know from atmospheric optics, light particles (both direct and reflected) are subject to scattering as they pass through the atmosphere. Most important, sca tering, in additional to having an overall effect, is also selective in nature, and affects differently radiation of differing wave-lengths.

The state of the atmosphere may vary. The atmosphere may contain only air particles, but this is relatively rare. Usually, the atmosphere contains larger particles of water, dust, and smoke, sometimes in considerable numbers.

The nature of the scattering of light by minute atmospheric particles has been studied by the British physicist G. Raleigh, who found that the intensity of the scattering of radiation by elements in the atmosphere whose dimensions were considerably smaller than the

wave-length of light is inversely proportional to the wave-length to the fourth power. Thus, the short-wave radiation in the spectrum (the blue-violet portion) is scattered more intensively than long-wave radiation (the red-orange portion). For this reason, a beam of scattered light contains many more blue-violet rays than orange-red ones.

Particles of larger size (1 micron and above) scatter all light equally, without modifying the spectrum of white color light. This explains the white color of clouds, and the greyish-white color of a cloudy sky. Penetrating among atmospheric gases, large particles increase the turbidity of the atmosphere, and add white to the blue color of the sky. A whitish color is observable in the air near the horizon, where the dust, water and smoke contents of the atmosphere are particularly high. Thus, an intense blue color of the sky is an indication of the purity and transparency of the air.

The transparency of the atmosphere may vary within broad limits, depending on the atmospheric particles and, in particularly, the larger particles present within it. As the distance between an object and the observer is increased and the transparency of the atmosphere is decreased, the brightness of the object tends to approach that of the sky as it moves away. In the end, the object cannot be discerned and becomes invisible against the background of the

sky. The causes of the decrease in the object's brightness are the scattering and weakening of reflected light traveling through the atmosphere. As a result of this phenomenon, some objects become lighter in color as they move away. This happens to ~~xNaxxoixax~~ forests. Other objects, such as snow-capped peaks, become darker: at close range, mountains appear brighter than when they are observed through a thick atmospheric layer.

As a result of a complex process of selective scattering and loss of light, the apparent color of objects thus changes. For example, the rays of the sun at the horizon near sunrise or sunset travel a longer distance through the atmosphere than they do in the middle of the day, and are considerably affected by selective scattering. Most affected is blue-violet radiation; the radiation that remains visible is mostly red and orange. This exaplains the characteristic pink and orange coloration of the sky at dawn. Clouds that are near the horizon and are illuminated by the rays of the sun also turn yellow and orange near the horizon, while remaining white at the zenith.

Atmospheric variations of light lie at the root of all visible changes in the color of objects, of the sky, the sun, etc. They all derive from the scattering and absorption of light by atmospheric particles. Aerial perspective, as an optical phenomenon involving the variation of the colors of objects, is

one of the manifestations of the effect of the atmosphere on light, and one that we witness daily.

29. The application of the principles of aerial perspective to the representation of relief.

All variations in the colors of objects caused by aerial perspective are usually observed by us in the horizontal plane. These variations are the ones that are most familiar to us. In a cartographic representation, we likewise use color variations that occur characteristically in a horizontal plane, despite the fact that our line of sight is vertical.

A broad range of color differences between objects removed at various distances is used in painting and allows for a realistic perception of distance. However, in the plastic representation of relief, the full range of color variations cannot be used. As previously stated, the colors of distant objects tend toward the color of the sky at the horizon, becoming whitish, and eventually blending with it. Those color variations that cause objects and their shadows to become whitish and discernible with difficulty are not used in the representation of relief. In a shadow representation of relief, even the areas farthest removed from eye must have contrasting light and shadow distributions, and be perceptible in all their details.

Therefore, in the plastic representation of relief, the range of color brightness is smaller than among colors observed in nature.

A multicolored shadow image, following the rules of aerial perspective, makes it possible to convey the relative elevation of major features of relief, of mountain chains and mountainous areas, which is obliterated in a monochrome image.

Aerial perspective involves variations in the color of shadows.

In the lower areas, shadows are veiled in haze and consists of violet and blue hues of little intensity. Separate features having more contrasting shadows rise out of them through a bluish mist.

Higher features of relief assume more definite outlines, their blue or violet coloration disappears, and the color of their shadows becomes greyish-green, olive, or brown.

Even higher features exhibit still sharper outlines, and their shadows are intense, dark, and at the same time warmer in hue: reddish-brown, dark brown, etc.

The variations enumerated constitute a specific example. In practice, the colors of shadows must be adjusted to those of the objects themselves and, for this reason, may assume various hues. However, the overall effect of aerial perspective is to cause the shadows of distant objects to approximate, regardless of their own color, greyish-blue, greyish-green and violet hues.

This range of color variation retains its applicability to objects removed both horizontally and vertically, when viewed from above.

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Variations in the color of shadows observed in nature are reflected in the representation of shadows in depicting relief.

In conjunction with the background (gypsometric) colors used in the representation of relief, shadow colors may vary from black, dark red, dark brown, dark gree and reddish brown for higher relief features through brown, olive, grey, greyish-green for lower features, to weak blue, light blue and violet shades for low and depressed portions of the relief, that are the farthest removed from the eye of the hypothetical observer.

Color variations are not only used specifically for shadows. Of great importance in achieving a plastic effect is the color background provided for the map, on which one shade grades into another in an orderly color scale. Most frequently, colors vary in relation to altitude. A color background, in combination with a shadow pattern, aids the achievement of a plastic effect and a visually effective rendering of relative elevation.

30. The plastic properties of color.

Every visible chromatic color is defined in terms of three properties: hue, intensity, and brightness. All color variations are due to the variation of one, two or all three of these properties

Variations in the color of objects that are removed

in distance also involve variations in color properties. The study of the laws of variation of each of these properties allows their use in preparing a multicolored plastic representation.

Hue is taken to mean that component of a color whose perception allows us to classify what we see by analogy to a particular segment of the spectrum or to the purple colors. Color distinctions designated as red, green, purple, are distinctions of hue.

The effect of atmospheric haze is to cause the hue of the object receding in distance to become mixed with blue. Optical mixtures of the most varied colors with blue results in a complex range of shades which have, in varying degrees, the property of appearing close or distant from the eye. This property may be understood as follows.

The colors of the visible portion of the solar portion, completed by the addition of purple, which is lacking among them, may be arranged in a circle. In essence, this circle contains all visible intense chromatic colors.

Within this circle of colors, we may roughly distinguish two groups of colors, differing in their properties. The hues of one of these groups are generally called warm, through their association with the color of fire, incandescent metal and solar light. The hues of the other group are called cool

because of their similarity to the color of ice, snow in the shade, water, and cold metal. Warm colors are classed as salient, while cool colors are receding.

Orange-red hues are considered to be the most salient, while various shades of blue are the most receding. Green colors are considered more salient than blue ones, but less so than yellow and oranges. Purples stand out more than blues and violets but less than reds.

The intensity of a color is defined as the degree to which a chromatic color differs from an achromatic one at equal brightness. The more white, grey or black a color contains, the less intense it is. The less white, grey or black it contains, and the more particular hue is discernible within it, the more intense it. Intensity describes the purity of a color, i.e. the absence of an achromatic component within it (Fig. 25, c)

The colors of distant objects lose their intensity as a result of atmospheric haze, and become less pure and less noticeable as colors. These changes determine the effect of intensity on the salience or recession of a color. At equal brightness, an intense color stands out, while a color of low intensity recedes. The more pure a color, the closer it appears.

Observations show that salience increases most with intensity in the warm colors; yellow, orange and red. However, in the cool colors as well (light

blue, blue, blue-green) intensity affects the salience of a color on a background of lesser intensity.

The combined variation of hue and intensity affects the spatial properties of colors to a much greater degree than the variation of either component separately. For example, intense coloration in orange or red hues stands out against a bluish green or blue-violet background of low intensity.

Brightness defines the intensity of a light beam reflected or emitted by a given body.

An example of variation in brightness may be seen in an achromatic series consisting of shades ranging from white through light grey, grey, and dark grey to black. (Fig. 25a).

A chromatic series of varying brightness may be obtained in practice by gradually overlaying this series, from one end to the other, with some color, or else superimposing a series of shades of grey over a monochrome colored surface (Fig 25b). In both cases, color intensity varies along with brightness.

Depressions, into which relatively little light penetrates, appear darker than protruding features. The deeper and narrower a depression, the darker it appears. The causes of the weakening of illumination in depressions are the reflection and absorption of light. The regularity with which light weakens within depressions is responsible for the fact that dark colors,

obtained through the admixture of achromatic tones, appear receding, while light colors appear salient.

The property that colors have of appearing salient or receding xxx, also known under the name of chromatic stereoscopy, has been studied by color scientists and physiologists.

The physiological nature of this phenomenon has been connected with the eccentricity of the pupil. Other investigators have suggested that the refraction of light rays by the refracting layers of the eye lies at the basis of the phenomenon. Blue radiation is refracted to a greater degree than red. Other radiations within the spectrum vary between the two extremes in proportion to their proximity to blue and red.

In most people, the central depression of the retina is situated to the brow side of the point at which the optical axis passes through the retina. A beam of white light forms a short spectrum on the retina, and its blue range is closest to the optical axis. The focus of short wave-lengths is closer to the nasal side than that of long wave lengths. As a result of this distribution of focal points in both eyes, blue rays, if extrapolated forward into the field of vision, will converge further away than red rays. Therefore, blue rays will appear to emanate from a more distant object than red rays.

However, the properties of salience and recession are by no means unequivocally manifested or convincingly manifested in all cases. A well-known experiment in this connection is that of G. Helmholtz, who tested the relation between the apparent distance of objects and the extent of accomodation, i.e. the adjustment of the refracting surfaces of the eye to clear vision at varying ranges. By observing two slits filled, respectively, with red and green glass, through a tube whose interior was coated with black, this investigator expected the red slit to appear closer than the blue one, since red rays are refracted to a lesser degree than blue ones and required greater accomodation. He managed to receive this impression on several occasions, but only with some difficulty. When the red slit was widened, however, the illusion occured more frequently, since the increase in size of the object became an additional factor causing it to appear at closer range.

Tests carried out by the Institute of Psychology of Moscow University lead to the conclusion that warm hues are not always perceived as salient in relation to cool ones. In these tests, the spatial position of every color was scaled in relation to red. When observing red and blue simultaneously, many people perceive blue, not red, as closer. Other people alternate in perceiving red and blue as closer, while some experience no illusion at all of any kind.

72% perceived red as being closer than blue, 28% do not experience this illusion, while 11% perceive blue as closer than red. At the same time, 77% perceive red as closer than yellow, while 57% see red as closer than green. If assume that these percentages express the degree of removal of each color from red, then colors may be arranged in order of their recession as follows: red, green, blue, and yellow. This is not the order of the spectrum, which is red, yellow, green, blue, which might be expected to hold true if we accept the theory of the accomodation of the eye to various hues of the spectrum.

In studies of chromatic depth perception, Hartridge (USA) has come to the conclusion that red is salient, blue is receding, while other other hues of the spectrum occupy positions between the two depending on their wave-length. However, this rule would apply mainly to colors seen against a black background. When a color scale is placed against a white background, chromatic depth perception departs from these rules. The reason is seen as the following. A red hue on a white background reflects red, orange, and some yellow rays. A white background reflects rays of all hues. The difference between them consists in the fact that red does not reflect

green, blue-green, blue and violet rays, which are reflected by the white background. Thus, the eye is stimulated both by the uniform expanse of red and, in addition, by blue-green radiation, and both contribute to depth perception.

The relative stereoscopic effects of various colors as determined by Hartridge are given in Table 1.

Table 1

Apparent position	Hue on black background	Hue on white background
Closest	red	blue-green
Close	orange	indigo
Not very close	yellow	blue
Median position	green	purple
Not very far	blue-green	red
Far	blue	yellow
Farthest	violet	yellow-green

As may be seen from the table, the hues in the second and third columns are complementaries.

In addition, Hartridge believes that most people with normal chromatic depth perception find that a black outline appears closer against a red background than a white outline and that, conversely, a white outline is more salient against a blue-green background than a black outline. The reason would lie in the fact that the stereoscopic effect of a black outline is determined by the color red, while the effect of

a white outline depends on the blue-green.

Closely connected to the problem of the salience and recession of hues is that of the apparent variations ofecolors as they are moved away or as the angle of vision is decreased when colored surfaces or objects are being viewed.

In color perception tests undertaken by the State Institute of the Brain Imeni V.M. Bekhterev and the Color Laboratory of the All-Union Academy of Arts, evidence has been gathered to indicate that variations in hue with distance depends both on the background and on the angle at which the color is perceived.

A law of critical points has been formulated, which serves to describe color variations as functions of range and angle of sight.

Certain colors, located not far from each other in the circle of hues, have a tendency to move toward one another in hue when viewed from a distance. The points toward which these colors move have been called "positive critical points". There are two of these. One is situated between the purple and red hues, the other, between green and blue. For other colors of the circle of colors, however, divergence in hue increases with distance. The points from which these colors move away have been called "negative critical points". One of them is situated between the yellow and yellow-green hues, the other - between

blue and violet.

A white background has the effect of shifting the color perceived toward one of the positive critical points and away from one of the negative critical points.

As the angle of sight at which colored surfaces are viewed is decreased, color perception varies as it would with distance. An orange hue against a white background becomes redder, while a green one becomes bluer. Eventually, the surfaces of objects lose their color and are perceived as achromatic. Thus, for example, the apparent coloration of ground objects tends toward the achromatic when viewed from an airplane.

In summarizing the results of research to date, the following emerges. In nature, objects or surfaces are interpreted as distant as a result of the combined effect of a number of factors: the decrease of the apparent dimensions of objects, the obstruction of one object by another, binocular vision, lighting causing variations in the distribution of light and shadow, and, finally, apparent changes in the coloration of objects. The role of color variation among other factors is apparently not clear cut or equal for all observers. In turn, the salient or receding effect of a given color results from such factors as color combination, background, angle of sight, the dimensions of colored objects, and so forth. The relative

importance of each of these in determining salience or recession, has not yet been definitely determined, and requires further study. Color combinations apparently do affect relative prominence of recession but, it would seem, judging from experiments, that they are most operative in combination with other factors, such as the distribution of light and shade. This receives support in the use of various color combinations for representing relief on maps, which is most effective when color and shadow techniques are combined.

Any color property taken separately does not convincingly convey apparent salience or recession. This is to be expected, since, in nature, the observation of objects at various distances involves overall color variation, not variations in individual components of color. Salience or recession comes through most effectively through the combined effect of all properties of color.

The plastic properties of separate color components counteract one another in a number of cases and this must be allowed for in an overall evaluation of spatial effect. As an example, we may use the opposite plastic effects of brightness and intensity. In setting up a monochrome chromatic series of varying value by means of the graded application of color layers, we cause simultaneous variations in both brightness and intensity, which vary in opposite

directions one from the other. Keep in mind that light colors are salient, while dark colors recede, we will expect to find that color salience increases with brightness. On the other hand, since intense colors are more prominent than colors of low intensity, color prominence will also increase with intensity. As a result, a color series will not manifest any clear-cut trend in the variation of the plastic properties if its segments.

In map-making, it is advisable to use a combination of colors that, upon the analysis of its component color series, will preserve an overall trend in the degree to which the plastic properties of color are put to use.

We may use, for example, a series in which one extreme is color that it both relatively intense and relatively bright. The other end of the scale should then be of considerably lesser intensity, while remaining relatively bright, so as to avoid the creation of a dark background. Other variants are also possible.

Generally speaking, effects of salience and recession must be considered undependable and variable.

However, there are no real grounds for denying altogether the plastic effects of color. We need only to refer to painting, in which artists make extensive use of the plastic properties of color in combination with chiaroscuro, and acheive convincing[a] and effective three-dimensional quality, borrowed from nature itself.

In nature, all lighted objects have both illuminated and shaded surfaces. Combined with coloration, which varies with distance, light and shadow serves to convey effectively the mass of objects.

To clarify the problem of the role to be played by color in the plastic representation of relief, it is necessary to study further the perception of salience and recession in colors and their application to the plastic representation of relief.

31. The nature of color variation in hypsometric scales.

In rendering relief in color, the principle most frequently used is that of hypsometric coloration, which consists in coloring the intervals between contour lines in shades related in some consistent way to those used in coloring adjoining intervals. All colored intervals taken together are said to constitute a hypsometric scale of relief coloration.

In a number of cases, hypsometric coloration may be used as an independent means of conveying relief. The color shades in a hypsometric scale used independently of other means of representing relief may attain considerable intensity. In this form, hypsometric coloration may improve the readability of relief to a considerable degree. Various shades of color may allow the arbitrary contrasting of low-lying areas, mountains, mountain ranges and large mountain formations, which is not possible through the use of contour alone.

However, representations of relief through hypsometric coloration alone do not have a three-dimensional quality and do not have the visual effectiveness that allows the perception of relief forms as solid bodies. Nevertheless, the color combinations of a hypsometric scale may serve to reinforce the plastic effect of a relief image created by using other means of plastic representation, such as tinting.

In modern map-making, hypsometric coloration is frequently used in conjunction with tinting, as a color background on which shadow effects are superimposed. The color background is then used to convey illuminated and semi-illuminated surfaces of relief features, while tinting is used to accentuate surfaces in half- and full shadow. This makes it necessary to adjust hypsometric coloration to the shadow image in hue, intensity and brightness. Particularly important is the adjustment of brightness, since it is essential to allow shadows to contrast with the background of hypsometric coloration.

The nature of color variation within the scale may vary. Colors, for example, may vary in such a manner that each is radically different from its neighbors and every color in the scale.

If sharply contrasting colors are used, the entire colored surface appears cut up into parts or layers, corresponding the varicolored intervals of elevation. In such a case, coloration cannot serve

as a background contributing to the plastic effect of the representation along with a shaow pattern.

The opposite, however, may be done, and the scale may consist of continuously grading colors.

A gradually varying color series, formed of related colors, is essential in acheiving depth in conjunction with a shadow pattern.

Modern cartographic practice tends increasingly to avoid the use of chromatically heterogenous scale, and to make use of scales in which tints are linked by relatively gradual transitions.

The following formulas are most frequently used in designing hypsometric scales:

a) the higher the elevation, the darker the color;

b) the higher the elevation, the lighter the color;

c) the preservation of constant brightness.

As a rule, any scale used in the hypsometric tinting of relief involves changes in all color components. Of paramount importance, however, are variations in brightness, and is they that are involved in the three formulas listed above.

32. Hypsometric coloration on the principle of "the higher the elevation, the darker the color".

In a scale built on this principle, the colors of elevation intervals become more accentuated as elevation increases.

A scale of this type is usually based on some

set of color combinations in which brown shades predominate. Modern maps using this type of scale show the lowermost elevations (0-200, 200-500 m) in green, which becomes lighter as elevation is increased, while higher intervals, rendered in combinations of orange, brown, red and red-brown tints, become darker as elevation increases.

A scale which becomes darker with increased elevation is often used in modern maps. One is used in the maps of the Large Soviet Atlas of the World, published in 1937-1939, as well as in the Hypsometric Map of the European USSR on a scale of 1: 1,500,000, published in 1941, and many other fundamental cartographic works.

A progressively darkening color scale may also be used on maps which make use of shadows in rendering relief.

In combination with the tinting in of shadows, the dark background created by the coloration of the higher intervals does not permit the reading of shadows and the achievement of a plastic effect.

However, some maps make use of a modified darkening scale. No sharp contrast exists between the various gradations, and this permits the preservation of relatively light shades even in the higher intervals, and these can then blend and contrast, to a sufficient degree, with the shadow pattern. Low-lying areas are colored in soft-

greens of low intensity, while intermediate elevations are rendered in yellow and high mountains are orange-brown. Such coloration allows the easy recognition of basic elevational zones on the basis of color (Fig. 26).

33. Hypsometric coloration on the principle "the higher the elevation, the lighter the color".

A scale based on this principle is distinctive in that colors become less accentuated with km elevation (Fig. 27). The hue of the color scale also undergoes variation. The lower elevations are green, which grade into olive as elevation increases, then becoming brownish, pink and, eventually, orange or yellow-orange. Intensity is also made to vary.

Scales of this type have been used in physiographic maps published in 1938 in accordance with a decree of the government of the USSR. A similar scale is used in the map of Switzerland at 1:500,000 made by E. Imhof. A scale of increasing lightness provides a color background on which shadows appear clearly, particularly at high elevations, contrasting with illuminated surfaces and thereby satisfying the main requirement for plastic effectiveness. The use of a scale of increasing lightness without the simultaneous use of a shadow pattern is not very effective.

A scale of increasing lightness may convey aerial perspective, providing color intensity is higher at

higher elevations, This condition is very important and, at the same time, hard to realize. To have color intensity lower at lower elevations than at higher ones, which are already characterized by un-accented, light colors of low intensity, it is necessary to add a depp achromatic color to that of the lower intervals, and thus to bring it close to dark grey. If this is done, low-lying areas, which usually constitute the greater part of a map, will appear as a dark background against which other elements on the map will lose their readability.

To reserve, within a scale of increasing lightness, a relatively light coloration for lower intervals, the darkest coloration may be given to intervals of intermediate elevation, whence colors may be made to become lighter both upward and downward.

The necessity arises to provide an intense color for higher elevation intervals, and a relatively light color for the lower ones. In practice, this leads to the equalization of brightness throughout the scale or its variation within only narrow limits.

The results of this may be the creation of a scale of even brightness or of slightly varying brightness. Scales of this type are used in map-making.

34. Hypsometric coloration on the principle of even brightness.

A scale in which brightness changes little or

is kept constant makes it possible to apply the principle of aerial perspective, combine a colored background with a shadow pattern, and acheive, therefore, a plastically effective representation. Usually, in a scale of this type, brightness as well as hue and intensity, is subject to some variation, but it is not as marked as in either of the preceding types. On the one hand, mountain summits do not appear whitish, as they do in a scale of increasing lightness, while, on the other, they are not as dark as in the scale of increasing darkness. This type of scale has been used most widely in recent years, in particular on some maps published for institutions of higher learning. At the same time, a number of shortcomings are evident in these maps: color combinations are worked out ineffectually, and the quality of the shadow pattern, as printed, is poor, causing much loss of depth in theimage.

In working out a color scale, it is imperative to make an allowance for aerial perspective, and this requires the use of greens of low intensity for low-lying areas. Such colors must be sufficiently divergent from the bluish shades used in representing illuminated surfaces. High mountains should be rendered in colors which retain their lightness when they are made intense, so as to differ from the light and shadow pattern. Such colors include yellow, orange, and orange-red. Intermediate elevations should be colored in shades ranging from green through greyish-

green, olive, grey, brown and pink to orange, with a gradual increase of intensity with altitudes.

This type of scale is susceptible of having different color contents. Fig. 39 gives one example of a map rendered in a scale of constant brightness.

35. The development of plastic color representation with reference to the physiology of vision.

A number of attempts have been made in cartography to perfect plastic representation with reference to the physiological aspects of color perception.

Toward the end of the XIXthe century, K. Peucker proposed a hypsometric scale, in whose color combinations he established three continua: those of light power, color fullness (intensity) and that of the spectrum.

The continuum of light power was predicated on the principle ("the lighter the color, the closer it appears to the eye", and finds its justification in the fact that, invviewing dark colors, as in viewing distant surfaces, the pupil widens while, in viewing light colors and close surfaces, the pupil contracts. The eye responds to that which is light in color in the same manner as to that which is close, and to that which dark in the same manner as to that which is distant. The principle of the light power continuum parallels that of "the higher the elevation, the lighter the color".

The continuum of color fullness (intensity) was designed on the principle "the fuller (more intense) the color, the closer it appears to the eye", and is intended to allow for the effect of aerial perspective, which comes into play when viewing a landscape. A decrease in color fullness occurs as a result of the increase in the thickness of air layer between the eye and the object. The air acts as a bluish-white veil of increasing opacity.

The continuum of the spectrum is made to include colors in the order in which they occur in the solar spectrum. The basis for such an ordering of colors lies in the physiologic characteristics of the visual perception of the spectral continuum.

Red is perceived as being in the foreground, while other colors (orange, yellow, green and violet) are seen as receding further away in the order of their occurence in the spectrum.

By combining these continua, K. Peucker designed a scale for the hypsometric tinting of relief, to be used totally or in part. The scale consisted of 15 color gradations, and was termed the "spectral-adaptive" scale. The upper range of is a dark red (cinnabar) color, while the lowermost gradation is grey with a faint admixture of blue. Intervening divisions are colored greyish-green, green, yellow, yellow-orange, orange, and orange-red. Intensity increases with elevation.

A weak point in K. Poucker's scale is its departure from realistic color combinations such as occur in nature, where we observe variously colored objects under conditions of illumination and distinguish shaded (darker) and illuminated (lighter) surfaces. In the scale he designed, K. Peucker placed his major emphasis on the plastic properties of color, assuming, for example, that the principle of "the higher the elevation, the fuller the color" (i.e. the principle of unlimited intensification of color) would ensure a plastic effect. The higher intervals of elevation, colored in dark, intense reds, contrast well enough with the background created by the other lighter colors. However, the result is not the definition of salient features of relief, but merely the definition of dark, intense color areas on a lighter background. The tinting-in of relief on examples executed by him is done in weak grey shades, and can be read only in the lighter areas of the hypsometric scale. In the higher hypsometric intervals, colored red, where a plastic effect is particularly to be desired, shadows are not visible. K. Peucker neglected the color relations of illuminated and shaded surfaces and, as a consequence, the scale he designed failed to create a plastic effect. It is purely conventional in nature, like most scales of increasing darkness. K. Peucker's scale was

never used in cases when a plastic rendition of relief was required.

At approximately the same time as K. Peucker, but independently of him, the Swiss cartographic artist G. Kümmerly also came to certain conclusions regarding the salience and recession of colors. Taking part in a competition to produce a map of Switzerland at 1: 200,000, which was published in 1902, G. Kümmerly applied these conclusions in that particular map. By studying color combinations in nature, observing color changes during sunrise and sunset, and recording certain effects through painting in his "mountain color studio", he did not confine his efforts to the plastic properties of color, but used these in combination with the plastic properties of shadow patterns, and incorporated both in representing relief.

The salience of warm colors and the recession of cool ones, the contrasts created by light and shadow, and the principle of aerial perspective were the principal means which allowed him to represent relief through painting. Though Kümmerly did not use hypsometric coloration in the previously mentioned map, the overall variation of the colors in it, particularly in illuminated portions, are consistent with changes in elevation, going from cool colors of low intensity (grey-green) in low areas to intense warm colors (orange) in high regions.

The previ usly mentioned map of Switzerland is still used in schools both in Switzerland and outside of it.

Note must also be made of Freitag's scale, which has been in use for many years in the hypsometric coloring of relief in combination with tinting and hachuring. The scale begins with green colors of low intensity in its lower ranges, and passes through yellow to orange and intense orange for the higher intervals. As a whole, the scale is designed on the principle "the higher the elevation, the darker the color", but the darkening is moderate, even in the highest intervals. The ~~xxtix~~ entire scale remains relatively light and it best classified, perhaps, as a scale of only slight variation in brightness. In combination with shadow patterning, the scale makes it possible to ~~xffxxt~~ acheive considerable plastic effectiveness in representing relief.

In map-making, an applicable principle is that of reproducing natural coloration as it occurs in nature (colors of the plant and soil cover, colors of outcrops on the earth's surface), of combining the effect of haze with the actual colors of objects and ~~of duplicating~~ light and ~~shadow distributions~~ natural lighting conditions (light from the sun and light from the blue sky, falling on the surfaces of objects on a sunny day), both of which modify natural colors to a considerable degree and affect the plastic qualities of an image of relief.

~~Thisxp~~ This principle has repeatedly been the basis,

in Russian cartography, of expressive renditions of relief.

One of the earliest examples of the use of natural colors in conjunction with realistic conditions of illumination are the hand-drafted maps of the Swiss Campaign of 1799.

Among contemporary Soviet cartographers, a special place belongs to P.A. Skvortsov who has been working on the plastic properties of colors and their application in cartography.

The researches of P.A. Skvortsov to date are already reflected in a number of manuscript maps, in which a realistic depiction of landscape features occurs together with plastic relief representation* These

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* Among them we might mention the following color originals: Caucasus on a scale of 1: 500, 000; Africa, at 1: 6,000,000; South America at 1: 6,000,000, Abkhazia at 1: 200,000 and others.

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works are particularly explicit in making use of the effect of aerial perspective along with light and shadow distribution. Most remarkable, in these maps, however, is the harmonious combination of color and shadow plastic effects, which are perfectly blended.

The work of P.A. Skvortsov is not merely a series of practical experiments. On the contrary, it embodies years of painstaking research both concerning the color

scale to be used in cartographic representation, and investigations of the psychophysiological aspects of vision and the physical properties of color. The researches of P.A. Skvortsov, which constitute a fundamental contribution, remain to be published and, it should be expected, will constitute an important advance in the development of the theoretical foundations of the plastic representation of relief.

Other cartographic efforts of similar nature include G. Kümmerli's map of Switzerland on a scale of 1:200,000, published in 1902. The principle of aerial perspective is also used in the multi-sheet American map of Alaska at 1:250,000 published in 1952, where simple means and a limited number of printed colors succeed in conveying a plastic effect.

In designing a color scheme for the background of map, allowance should be made for the effect of each individual color in deciding the extent of its distribution.

Thus, for example, green is very important in a hypsometric scale for conveying aerial perspective. It should be used not merely up to the 200 m contour, as is usually done on maps, but as high as the 1000 m contour and even higher. At the same time, it is of course necessary to vary the shades of green used in relation to the extent of the surfaces on which they are to be used, blending them in the direction of olive and brown and varying their intensity and brightness.

At higher elevations, greens should be replaced with olives, browns, yellow-greys and greys.

The highest elevations should be rendered in colors of greater purity, such as pink, orange, and yellow-orange, which most effectively convey the illumination of relief features.

Chapter V

TECHNIQUES AND METHODS OF REPRESENTING RELIEF THROUGH SHADOWS

36. Supplies, equipment and techniques for representation.

One of the most prevalent techniques in modern cartography is the tinting in of relief. In this process, depicted shadows are "washed" in with a brush, whence the Russian term for the technique.

Tinting is done with india ink or water colors. Originals intended for industrial reproduction are executed in black india ink.

Powdered india ink is ground in a glass container with a roughened bottom. If pre-ground ink is available, a porcelain container with a smooth bottom may be used, and the ink dissolved in water in it.

The basic requirement of india ink is that, upon prolonged grinding, it yield an intense black coloration. In addition, india ink should not have a bluish tinge or be absorbed by paper with undue rapidity, since, in the latter case, undesirable spots will appear in the finished drawing.

The dry india ink "Red Painter" generally used

in this type of work has the disadvantage of rapidly thickening, curdling and forming grains, and then requiring replacement by a fresh batch. One of the means of averting premature thickening is carbolic acid. To ensure the preservation of the ink, it is enough, when diluting it or grinding it, to add 2 to 4 drops per container of a 2% solution of carbolic acid, such as may be purchased in a drugstore, Certain types of China ink, which come in the form of sticks or tablets, are of a better grade than dried ink of the "Red Painter" kind.

Concentrated "Red Painter" black india ink, of the kind that is put out in tubes, is quite adequate. It has the advantage of requiring very little time for its dilution. In diluting this ink, it is recommended, likewise, to add carbolic acid.

Since certain parts of the drawing will have to be rendered in a dark shade, it is advisable to keep on hand a second container with darker india ink.

Two-ended paint brushes, round in cross section, are the most convenient for tinting. One end is used for applying the ink, the other for applying wash. In washing out and re-applying ink it is necessary to rotate the brush in one's hand. The length of the brush should be such that it is convenient to work with either end of the brush after turning it over without having to change one's

grip. The average length of this kind of brush is about 14 to 16 cm.

It is a fairly easy matter to prepare such a brush out of two others. The metal clasp holding in the hairs is taken off the end of one brush, either by scaling it loose. The handle of the other brush is then shortened to the desired length of the projected two-ended brush, and then capped with the metal clasp and tip of the first brush.

The accurate application of shadows requires that the hairs of the brush be soft and at the same time relatively resilient, so that the tip of the brush maintains its shape in the course of its use. The hair that best satisfies this requirement is that of the red marten. Marten brushes, which are dark yellow in color, are the most suitable for this type of work. Polecat, squirrel and other types of hair are of lower grade. When wetted, the tip of the brush should assume the shape of a cone and have a pointed end.

The size of the brushes used in tinting will depend on the dimensions of the relief features depicted and the scale of the map. However, of all the sizes with which it is possible to execute a given design, it is important to choose the largest, since this it will ensure economic performance and, to a degree, prevent the superfluous particularization of the image. Most frequently used are Nos. 4, 6, 8 and 10. In preparing

a two-ended brush, it is recommended to join two different sizes, for example, a No. 6 for ink, and a No. 8 for water.

The paper on which the drawing is done must be evenly sized, have an uniform white color throughout its surface, and not turn yellow from exposure to light.

If the paper is not adequately sized, ink is absorbed very rapidly, cannot be washed over, and forms spots.

Inequalities in the color of the paper prevent a correct visual appreciation of the shadow pattern and, when photographed, may cause blotches on the photograph and even make it necessary to redo the original completely.

Hand-screened Goznak drafting paper, which is the most frequently used, is quite suitable for tinting, but sheets occasionally occur that are inadequately sized or that have a yellowish stain. Before beginning work, it is necessary, therefore, to examine the sheet selected, comparing it with other samples, to determine whether it is suitably white and whether ink can be properly washed over on its surface. A prior examination and checking of the paper is most essential if it is to bear representations of contour lines in blue and other map elements.

Before beginning work, the paper should be cleaned with a cotton wad soaked in water with a slight admixture of ammonia, to eliminate from its

surface all dust and other particles, as well as traces of oil and grease. This must be done very carefully, so as not to disturb the arrangement of the fibres on the surface of the paper or impair the sizing.

For convenience in working and the preservation of the drawing, the paper should be secured to a drawing board or a blind frame with drafting tacks or paper tape. Upon drying, the paper is stretched and remains mounted until work is completed. When tape is used for mounting the paper, it should be coated with glue (mucilage or all-purpose glue "Slon") and then applied along the edges of the sheet of paper, so as to adhere simultaneously to the paper and the board.

In executing originals for industrial reproduction, which have been mounted on a firm backing, the paper does not need to be fastened down, though it is essential that be cleaned with water.

The draftsmen proceeds to execute his project once the paper has dried out.

During his work, the drawing board or frame should be placed on a table in inclined position. The light must come from the left. On the right-hand side of the table are placed containers with india ink, a glass of water, a sheet of blotting paper, an eraser, a pencil and a brush. The cartographic and materials and written sources used in the course

of the work should be placed at the left of the draftsman. As the work proceeds, the completed drawing is covered with paper, the parts where washing is applied being likewise covered. A piece of paper is also placed under the right hand, to prevent the drawing from becoming soiled or stained.

To begin tinting, the draftsman dips both ends of his brush in water, then dips one in ink, wipes off the excess of ink on the blotting paper by drawing the brush across it, applies the ink where it is needed on the paper and, if necessary, washes over the shadow thus applied with the other end of the brush, having turned the brush over in his hand. If, for example, a relief feature is sharply defined on one side, while being gently warped on the other, the shadow is made to stop abruptly at the former, while being washed over on the side of the warping.

Certain shadows are not washed over after application. In this case, tinting is effected by using only one end of the brush.

In the course of his work, the draftsman uses blotting paper to dry one or the other end of his brush and reestablishes its pointed outline. It is not a good idea to put the brush in one's mouth, particularly if the diluted india ink contains carbolic acid.

The shading in of relief is infrequently used at the present time, though it may be used successfully

inmplace of tinting, as a number of examples from different times and places show, and is ~~much~~ less expensive of time than tinting. The use of photography in reproduction makes it possible to apply shading, like tinting, on white paper and then to photograph the resulting original. Very minute features are difficult to draw in by means of shading, but at scales of 1: 2000,000 and above, shading is capable of rendering all required features. Shading is also quite adequate for school maps at smaller scales, including 1:5000,000.

For shading, intended for photographic reproduction, the items required are white paper with a smooth surface, a black shading pencil, a felt-tipped or soft paper stump, and a soft eraser.

In shading, shadows are applied in pencil, then with a shading pencil ~~rubbed~~ to obtain smooth transitions between light and shade. Sharp shadows are not rubbed. Details are entered within the shadows also without rubbing. In shading, it is even more essential than in tinting to place a sheet of paper under the hand so as not to soil the drawing.

In tinting or shading, it is customary first to apply weak shadows, which are then made more intense where necessary. In superimposing these shadows, a shading pencil may be used again, or the existing shading may be intensified with an ordinary pencil.

A shadow pattern may also be obtained by use

of ~~xixixixix~~ hachuring. One of the merits of hachuring is the relatively simply technique involved, which allow the photographing and ~~xxxxxxxxxxx~~ preparation of printing dies without using a grating .

A hachured drawing may be executed according to several different principles. For example, maps of the XIXth and beginning of the XXth centuries made use of hachures of definite thickness, oriented in the direction of the watershed. This method requires the careful drafting of each hachure separately, and is very expensive of time.

A hachured drawing executed by pen may also consist of hachures that cross one another in various manners and result in shadows of varying intensity. This method yields positive results. The intensification of shadows in a hachured drawing is distinctive in technique: it may be effected by thickening the hachures or by having a new set of hachures cross over one previously applied. In this, it is important to watch that the intervals between hachures are not blacked out. The hachures must be solid black in color.

Corrections in tinting, shading and hachuring are entered with a soft eraser, hard eraser, and a scalpel. In using an eraser, it is advisable to use a templet cut out of firm paper or vinyl which will delimit the area to be cleaned, and will allow complete erasure.

If an erasure is not sufficient to eliminate an

item, final cleaning may be done with a scalpel. After cleaning a drawing with a soft eraser or a scalpel, it is essential then to rub the drawing with a hard eraser, to even out and buff the surface of the paper, and then to wet the area with a solution alum. Once this dries, the area may be worked upon once more.

37. Cartographic and other sources used in a representation of shadows.

The general requirements which a shadow representation is expected to satisfy may be formulated as follows:

a) that it convey the distribution of relief features;

b) that it convey the type of relief present;

c) that it convey a three-dimensional effect.

These requirements are fufilled by relying upon ~~the source materials provided by~~ the base map for which a shadow pattern is being prepared, and by bringing in other relevant information which serves to complete the ~~source~~ base map.

All the elements contained in a map are relevant to the representation of shadows in relief and, in some degree, may be used as references and checks in establishing the distribution of light and shadow.

~~Source~~ Base maps for tinting in relief may be divided into two classes: those ~~xxxxxxxxx~~ containing contour lines, and those lacking them.

Contour lines constitute a reference pattern which conveys in precise form the distribution of

relief features, relative and absolute elevations, the inclination of grades, types of relief, the orientation of mountain ranges and other orographic features, and other minor fx elements.

Contour lines are thus a basic source, and may sometimes ensure, by themselves, an adequate and total tinting in of relief. The task of the artist is then to read, with accuracy and ease, any type of relief expressed in contours, without having to depend on calculations or measurements, and to create on this basis a representation of the distribution of relief features. The reading of relief from contour lines is thus a necessary step, without which a shadow pattern cannot be executed.

The elements of a map, such as the drainage network, the shore lines of lakes and oceans, population centers, the road network, and ~~xxxxxxxx~~ administrative boundaries, are also significant in executing a shadow pattern. In a given area, they are all linked to relief features, and the connection must be made clear in their representation.

The drainage system is a framework which determines the distribution of ~~xxxx~~ negative and positive features of relief. Guided by the indications of the drainage network in a mountainous area, it is possible to locate major watersheds and ranges. The very pattern of the drainage itself may serve as an indication of the nature of the relief: streams with numerous meanders

and cut-offs are typical of broad valleys in low-lying areas, while straight, ~~xxx xxxxxxxxx~~ courses without bends are typical of mountainous relief.

The more completely a map conveys the drainage, the more it aids ~~xx~~ an accurate rendering of relief features.

The representation of relief must be coordinated with that of population centers, particularly the larger ones. It is ~~xxxx~~ difficult, for example, to imagine a large population center situated on a ~~xxxx~~ 45° grade, or on a mountain crest, or spanning a steep-walled ravine, etc. Yet, all these improbable situations may actually be found on maps. Such absurdities are particularly conspicuous when population centers, represented on maps by large circles, overlap not only a mountain side, but a mountain crest and its opposite slope. It is essential to show light and shade distributions in such a manner as to have important population centers occur on horizontal surfaces or on relatively gentle slopes. If relief is to be represented on a school map, intended to hang on the wall, and the population centers must therefore be enlarged, shadows should be ~~xxxxxxx~~ shifted over, in accordance with their size and shape, so as to coordinate them with the location of towns and others elements.

No less important is the coordination of relief with the representation of the road network. In mountainous areas, where steep grades predominate, roads are

rarely oriented in a direction perpendicular to that of mountain ranges. Usually, to lessen the grade, roads rise from the foot of the slope in a diagonal direction, or else curve around in "hair-pin" fashions, and cross mountain chains at passes or troughs. To allow for this, it is important to check the distribution of light and shadow against the orientation of roads, emphasizing passes and troughs, and placing shadows so as to have roads rise up slopes at an angle, and having roads cross mountain chains at right angles only when such is actually the case.

Administrative boundaries in mountainous areas, particularly those between different states, often follow natural boundaries such as mountain ranges, streams, etc. In such cases, it is important to check the distribution of light and shadow against the position of frontiers.

For purposes of publication in preparing a tinted original, the same base map is used as the one to be used in the combined printer's original. If contour lines define the relief adequately, other elements of the map, with the exception of drainage, are not transferred. Only pencil markings are used to indicate the position of elements which must be matched in both drawings. If, however, contours fail to adequately convey relief, or are lacking entirely, all elements

of the finished map must be entered on the artist's base map.

In a number of cases, the base map is not enough to ensure the accurate execution of a shadow pattern, which will fulfill all the requirements expected of it. In such a case, use must be made of cartographic and written sources which will allow a better rendering of relief through tinting. Of particular importance in this case are maps representing relief.

The preparation and utilization of source materials requires particular attention.

Source materials may be classed, in accordance with the nature and completeness of the information they contain, as basic and supplementary.

Basic sources include:

a) maps with plastic representations of relief (by hachuring, shading or tinting). These may include maps in atlases, separate maps, as well as multiple sheet maps in which relief is conveyed in a plastic manner. The latter characteristics makes such maps much easier to work from than maps in which relief is represented by other means.

b) Maps in which relief is represented by means of hypsometric coloration or contour lines. This group includes a number of different kinds of maps, differing in purpose and scale, and is most frequently used in preparing shadow patterns. However, contours

alone, particularly in small-scale maps, do not convey entirely the type of relief present, and require the supplementary use of photographs, drawings, descriptions, etc.

c) Terrain models and photographs of terrain models. This group is likely to be quantitatively limited in size, but are effective visual sources for the distribution and nature of relief. If lighting conditions are the same in the model and in the pattern to be executed, the creation of the latter will be considerably simplified, though it will not be reduced to a simple transfer of relief features. The drawing must be reinterpreted: contrasts, for example, must be exaggerated, on the assumption that they will be weakened through photography, relief features must be generalized from the model, and so forth.

Supplementary sources include:

a) Individual and mosaic aerial photographs. Aerial photographs matched with the map for scale, have short, small and fragmented shadows, and, therefore, fail to convey effectively both major and secondary features of relief. The presence of many other elements, sometimes creating a dark background, also limit the recognition of relief features. The lighting in aerial photographs does not usually agree with that assumed for the tinting in of shadows on the map. A mosaic of matched aerial photographs often exhibits sharp contrasts of tonalities, and this is particularly obvious where photographs meet

and creates obstacles to their use. For this reason, aerial photographs are not highly suited in preparing a shadow pattern. Their usefulness resides mainly in allowing the study of the nature of the relief.

b) Oblique photographs and drawings are very valuable, and make it possible to judge of the structure and nature of the relief. They are mainly helpful in drawing in individual features of relief in a representation by means of shadows.

c) Geographic descriptions. The utilization of descriptions boils down mainly to gathering information on the type of relief present and the main orographic features. The distinctive characteristic of descriptions, the fact that they convey information in expository form, does not allow an accurate representation of features of the terrain and of their distribution. However, as adjuncts to basic sources, such as maps representing relief, descriptions may make it possible to determine the nature of relief in specific areas.

The nature of the base map determines the type of source materials which will be used. For example, if a shadow pattern is drawn in on a physiographic, hypsometric or topographic map, on which relief is represented by frequently-spaced contours, the base map itself ensures the proper execution of the shadow pattern. Other materials (such as photographs or descriptions) can only yield additional details

regarding the nature and features of relief. If, however, a shadow pattern must be drawn without reference to contour lines, use must be made of other sources from which a shadow pattern may be derived, and these must be prepared for use.

38. The preparation of source materials and a base map for use.

Regardless of the class to which a source belongs, if it is to be used in preparing a shadow pattern, it must be examined and evaluated to determine the extent to which it can be utilized.

Materials are evaluated by comparing them with one another, with allowance for their date and other characteristics.

Examination and evaluation are done as follows.

An estimate is made of the completeness of the data yielded by the source, i.e. whether it conveys fully all the orographic features which are to be shown on the map. If the required features are lacking in the source, other sources bearing on these features are sought. Conversely, if the source contains unnecessary details, these are marked, in some manner, as unessential.

An evaluation must also be made of the reliability of the information contained in the source, i.e. an opinion is formed as to whether the source ensures the accurate localization of all orographic features in the shadow pattern, So Prot the most important ones.

are conveyed and the ~~the~~ true nature of the relief is appreciated. The information provided by the source may be out of date, or the source itself may be of low accuracy and contain errors. The reliability of the information in a source depends on the date and manner of its acquisition, and may be checked only by reference with other materials, more recent and more accurate, which, for one reason or another, ~~cannot~~ are not be used as sources ~~in~~ for the shadow ~~image~~ drawing. Sources which are wanting in accuracy, must be corrected or replaced by other more reliable ones.

Also to be evaluated is the manner and degree of success with which the relief is conveyed. A correct understanding of the nature and distribution of relief features depends, in large measure, on the manner in which relief is represented on the cartographic sources used, and the degree to which this representation is effective.. Also of considerable importance is the quality and the faithfulness of reproduction in print of the representation. A low grade representation may lead to errors in tinting in the relief.

Examination of the sources involves the graphic notation of all changes and corrections either on the sources themselves, or in their margins. If the representation is of low quality and annotations become too numerous, it is advisable to use another source.

The cartographic sources employed may differ in their scales. However, if a choice has to be

made between sources, preference should be given to the one whose scale most closely approximates that of the drawing in preparation: closeness in scale allows the visual comparison, in the course of the work, of the source and of the drawing in preparation.

The examination and evaluation of the source material should be done either by the editor of the map, or the artist executing the tinting, if he has sufficient cartographic training and is capable of evaluating the quality of the materials.

Immediately prior to proceeding to the execution of an original shadow drawing, the artist must familiarize himself with all the source materials gathered, with the object of gaining a clear idea of the nature of the relief he is to depict, the degree to which it needs to be generalized, and the manner in which major features will be distributed. On the basis of the source materials, the artist must gain a conception of the types of relief features that predominate in a given area: whether they are sharply defined or rounded, ~~their~~ what their structure is, where plateaus and ranges are located, how they are oriented, whether parallel to one another or at various angles, how mountain spurs are oriented, etc. In familiarizing himself with relief features, the artist should at the same time plan and consider a lighting arrangement that will be most effective in conveying both individual features and the relief as a whole. Having reviewed

available materials and planned a lighting arrangement, the artist should be in a position to visualize with comparative accuracy the distribution of major orographic features and the location of the higher elevations so that, from the very outset, he will have a preliminary idea of how the intensities of light and shadow will vary in conveying given features.

In a number of cases, it will be found that the base map, especially if it lacks contours, is not adequate for obtaining an accurate representation of the relief. Inadequacies in the representation of drainage are likely to be most acutely felt. In such a case, it is necessary to use some of the gathered material to complete the drainage pattern as represented on the base map, as well as other, elements, if possible and if they help in determining the relief pattern.

After becoming acquainted with his sources, the artist draws up an orographic pattern by entering on the base map, which is printed in blue, lines and symbols which will indicate the position, value and characteristics of orographic elements and features of relief. These are entered visually in pencil, by reference to all the elements present on the base map and the additional symbols that have been entered upon it. If adequate reference points are lacking, use is made of a proportional compas or a complementary grid, derived from the

coordinate grid. The main reference element should be drainage.

The preliminary diagram should show the location of distinctive changes in relief orientation, indicate the nature of the relief (whether it is rugged, gently graded or rounded), and include notations of steep slopes, individual summits, their elevation in relation to one another, major and secondary orientations of ranges, the nature of stream valleys (whether broad or narrow). For clarity, commonly used and easily readable symbols should be used.

It is most efficient to proceed to the execution of an orographic diagram only after having first completed the blue base map with pencilled in drainage, amplified with hydrographic information transferred from other source maps. Hydrography is entered in pencil only in those areas where relief is to appear as tinting. Where tinting will not be applied (as, for example, on flat expanses), there is not reason for entering drainage.

The preliminary orographic diagram may vary in execution. If, for example, contours define clearly enough the watersheds which will occur as boundaries between light and shadow, there is no reason for entering them in pencil. In such a case, the orographic diagram need only contain basic structural lines which are not clearly expressed by contour lines. Conversely, on maps

which lack contour lines, it is essentialky to clearly mark in pencil all the lines separating illuminated from shaded surfaces. All of these, to the same extent as elements of drainage, are xxx essential in the subsequent process of applying shadows.

An example of an orographic diagram on a base map is given in Fig. 28.

For purposes of map publication, orographic diagrams are drawn by the artist concerned, and include only those elements that the artist feels are necessary for his task. It would be desirable to organize a compilation of orographic diagrams for all mountainous regions of the world, for example on a scale of 1: 1,000,000. Such a series might prove useful for drawing in shadows of relief in many maps at various scales.

The stage which is preparatory to the actual tinting in of relief is important. There more completely and thoroughly the artist studies all the sources, the more care is exercised in drawing up the orographic diagram, and the clearer the conception which the artist has of the relief to be conveyed and of its component features, the more realistic will be the resulting image of these features and thexhatchxx higher their quality.

39. The distribution of light and shadow on basic surfaces and forms.

In geomorphology, the following types of slopes

are distinguished in relief features on the basis of their profiles: straight, concave, convex, and undulating (Fig. 29a). The shadow pattern corresponding to each of these types is shown in Fig. 29b.

In classifying relief features, their apparent variety may be reduced by comparing them to a limited number of simple geometric forms, and this, in turn, allows to explain the distribution of shadows on them in a simple and understandable manner.

One such form, defined by straight slopes, is the pyramid (Fig. 30).

The pyramid is located on a flat surface and is lighted from the side, at an angle. The four visible boundaries of the pyramid have a different type of illumination, which also varies within the limits of each face.

Each shadow is shown as darker near its boundary with a lighter shadow than on the remainder of the face. A particularly dark shadow occurs toward the summit of the pyramid on the less illuminated surfaces. As a result of the effect of reflected light, the lower portions of these surfaces are shown as somewhat lighter than their boundaries.

The orientation of the light determines the direction in which the pyramid casts a shadow. In the vicinity of the pyramid, and particularly at its origin, the cast shadow has sharp boundaries and is darker than own shadow. As we move away from the pyramid, half- shadow appears.

within the cast shadow, the boundaries become more diffuse, and the shadow becomes lighter. The outlines of the cast shadow repeat those of the pyramid. The surface on which the pyramid stands is less illuminated than its illuminated faces, and is under an even, light shadow.

A cone, placed on a flat surface (Fig. 31), causes shadows that resemble, in many ways, those of the pyramid. However, the very shape of the cone, which lacks facets, determines a gradual transition from dark shadow to illuminated parts. At the summit of the cone, the shadow is just as dark as it is on the pyramid, and becomes lighter further down. Cast shadow, which is sharply defined and dark near the cone, gradually becomes less intense and more diffuse further away. The outline of the cast shadow repeats that of the cone.

A prism (Fig. 32) causes shadows that, in many ways, resemble those caused by the pyramid and the cone. However, a particularly dark shadow occurs along the ridge that separates the two long faces. The cast shadow is the projection of a prism on a plane surface.

Fig. 33 shows an hemisphere under side (a) and top (b) lighting. Under side lighting, a dark shadow forms in the lower part of the hemisphere on the shaded side. A light shadow forms on the lower part on the illuminated side. The lightest

areas occurx somewhat above this light shadow. Cast shadows are bounded by curves corresponding to convex surfaces.

Under vertical lighting, a dark shadow is formed on those surfaces that are inclined the most steeply. The central portion remains light, since it consists of horizontal and moderately inclined areas.

The switch from geometric solids to features of relief requires ~~the~~ a break-down of the latter into parts, and the rendering ~~of~~ on them of ~~minor~~ details resulting from erosive action, such as wind and other forces that destroy relief.

For the most part, mountain crests occur as ~~mountain~~ jagged lines. Ranges consist of alternating summits and troughs. The slopes of individual mountains, ranges and hill-like eminences are ~~extensively~~ dissected by ~~extensive~~ taluses, hollows and ravines. Summits may be peaked, rounded, plateau-like or contain craters, in the case of volcanoes.

Fig. 34 shows relief features that conform to the geometric solids previously discussed but which, in addition, exhibit some of the details that arise in the course of the development of relief.

The shadow patterns examined in connection with basic geometric forms are characteristic of isolated features of relief.

In rendering combined features of relief, it is important to convey not only the shadows of each

component form, but also to express the connection existing between forms, as well as their relative elevations, by means of shadows.

The shadows cast by specific features may, to a greater or less extent, obscure other features. Light reflected from illuminated surfaces, tends to weaken shadows in dark areas. Illumination and the contrast of light and shadow are more extreme on high features than on low ones. The outlines of cast shadows depend not only on the shape of the features that cast them, but also on the exposure, orientation and shape of those surfaces on which the shadows are cast. All these factors must be taken into account when representing complex features of relief.

The best aid to the study of shadow patterns is the sketching of solid bodies. It is possible to mold various solid forms out of clay or plasticine and to sketch them under varying lights. Shadows are perceived with particular clarity if the forms are painted white. In doing this, it is important to attempt to remember the resulting shadow patterns with the object of eventually applying them in practice.

40. The sequence of application of shadows.

In representing relief, the artist is likely to run into difficulty in deciding on the order in which he applies various shadows, and will frequently face the problem of whether to begin with general

shadows, that emphasize major features, and then to go on to those caused by details of relief, or vice versa. What is the most advisable sequence?

However, the important thing in obtaining a high grade representation is not some standard sequence of techniques which, one might think, should be inculcated in each artist ~~xxxxxxxxxxxxxxxxxxxxxxxxxxxx~~ on systematic grounds. It is quite possible, for example, to begin by applying broad grey bands to represent general shadows along mountain ranges. These, however, in the end, are no help to the artist in understanding the configuration of relief and, on the contrary, may get in his way by obscuring the pattern of contour lines. It is also possible to begin with shadows that convey details of relief, and end up with ~~x~~ such a variegated drawing, that it will be impossible to decipher.

The essential thing for the artist, at any stage in his work, is to be able to visualize what remains to be done to improve the representation and progress toward its completion, to gauge what is lacking or what is superfluous. It is essential for the artist to develop the knack of visually evaluating and checking the drawing in preparation at each stage of his work. The object of the artist must be see, in his mind's eye, the features of relief he is depicting, and to know in ~~xxxxx~~ advance~~x~~ the results of any techniques he is to employ. In one shot, the artist

may find it necessary to apply a general shadow, in another to darken the shadow in a canyon, in another still to convey reflected light, and so forth.

It is essential to plan such a sequence of operations as will make each shadow, each technique applied an improvement over the preceding, and at the same time a point of departure for further improvements in the representation. The process of preparing a drawing is not one of distinguishing successive phases (general shadows followed by details or vice versa), but a continuous operation of perfecting the representation and approaching its final form.

Experience shows that it most convenient to begin by applying shadows to those features of relief that clearly differ from one another in the exposures of their faces and are separated by clear-cut depressions. Subsequently, these features may be generalized, and their details emphasized. In doing this, it is important not to apply shadows evenly, but to inject half-shadows in them from the very beginning, not to paint them on, but to wash them on. Let these washed out shadows appear initially incomprehensible to others. The important thing is for the artist himself to comprehend how they serve to convey solid forms, and to visualize the amplification they require for the gradual achievement of a finished representation.

The representation should not be elaborated part by part, but as a whole.

In the course of the work it is inadvisable to dwell on one spot for any great length of time. Prolonged concentration on any one spot causes the artist to see in that spot not solid forms, but merely aggregates of spots and stains, that fail to convey anything. In such cases, it is essential to pass on to other portions, so as to view each portion with a fresh eye. Only in this manner is it possible to perceive at a glance what further work a particular area requires. By shifting from spot to spot in this way, the artist approaches the completion either of the entire drawing, or of some large portion thereof.

However, in doing this, another concern should always be present; in interrupting work in a given spot, care should be taken not to leave it entirely unfinished. Therefore, after having worked in one or two other spots, it is essential to return to the first one, and to fill in the shadows that are still missing.

Fig. 35 breaks down the process of execution of a shadow pattern into sequential phases. First, a light direction is selected for the pattern. For the major features of relief in the example illustrated, it is advisable to select a north-northwestern light source. For secondary features in the west, a western source is desirable; for those to the east, a northern source. Then, light direction should coordinated for all features.

One of the most undesirable situations is to have neighboring orographic features of similar orientation shaded or illuminated slopes facing each other. In such cases, it is necessary to show one as being somewhat darker than the other, and to emphasize the shadows in the hollow separating the two slopes.

Work should be begun by applying light own shadows occuring on relief features that are distinct one from the other. The shadows should be washed on from the darker to the lighter part, from the summits and crests downward along the slopes, and should be relatively detailed, though minute details are generalized.

Where needed, cast shadow is applied, and is made to correspond in outline to the shape of the feature casting it.

Further work consists in intensifying own shadows, rendering detail, applying a light shade in flat areas, and intensifying highlights on illuminated slopes.

In the following phase, shadows are further intensified. Shadows serving to deepen hollows and setting off spurs both on their shaded and illuminated faces are depicted. The shadows occuring in flat areas, that emphasize the banks and the beds of streams, are elaborated.

In this manner, the entire image gradually near completion, though it still does not exploit the full range of half-tones between black and white, and the most salient features have not yet been made to stand out.

Prior study of the relief allows the artist, in the last phase of his work, to apply the shadows that will express the relation of individual larger units to one another. Thus, for example, completely black shadows are shown in the central part of the mountain group represented, to emphasize its rise above all other relief features. The rocky, jagged nature of the group is emphasized by cutting shadows abruptly, instead of blurring them in their lower portions.

A general shadow is applied whenever the artist finds it necessary. It may be applied only toward the very end to differentiate between illuminated and shaded slopes and to reveal major orographic trends.

In the example illustrated, flat expanses are covered with shadow, i.e. all surfaces are consistently and entirely shaded in accordance with their illumination. For purposes of publication, it is not customary to show shadows on flat surfaces, though this practice contributed considerably to plastic effectiveness.

The sequence of shadow application illustrated is intended to apply to monochrome representations, particularly tinted originals for publication.

The execution of polychrome representations, in the form of sketches, samples and colored originals for publication, follows somewhat different rules.

Let us examine one specific example of the execution of a polychrome original, combining a colored background following a hypsometric pattern, and polychrome shadows.

The initial phase consists in the execution of the color background in accordance with a predetermined hypsometric scale (Fig. 36).

The coloration of shadows under the rules of aerial perspective is made to result from the combination of two or three colors, such as violet, grey-brown and red-brown. Of these, violet is used in the lower and deeper parts of the relief, grey-brown shades attain higher elevations, while red-brown shadows are used to accentuate the highest features of relief.

The sequence of operations is the following. First to be applied are violet shadows, worked out for all features. These shadows constitute an underlying pattern for shadows of other colors (Fig. 37).

Next to be applied are shadows of grey-brown color, which are to merge gradually with those of violet color. On poorly illuminated surfaces, shadows are made to descend lower, while on well lighted surfaces they terminate higher up or are entirely absent (Fig. 38).

Red-brown shadows are laid over the grey-brown ones. They are the most highly contrasting, and, characteristically, do not blend gradually with grey-brown shadows. For the most part, the have jagged outlines, that penetrate downward along taluses, hollows and canyons. (Fig. 39).

In addition to possessing all the characteristics of a monochrome representation, this type also requires concern for an overall harmony of colors throughout the

drawing, and an attempt to avoid shadows of various colors that will appear as discrete entities instead of natural color variations caused by the superimposition of atmospheric haze over natural colors. In applying colored shadows, the following rule should be kept in mind: The intensity of a shadow increases with elevation; therefore, the red-brown shadows applied on the higher features should be the most intense.

The rules governing color combinations, both for manuscript and printed maps, may be stated as follows: Shadows of any one color should coincide with those of others along the lines of mountain crests, ridges, drainage lines and summits. Shifts and deviations from these common boundaries impair the effectiveness of light and shadow distribution. The replacement of one color by another as elevation changes must take place gradually, and this, in fact, is one of the main difficulties involved in printing a shadow pattern of this kind.

41. The generalization of relief features in a shadow pattern.

Like other types of cartographic representation, rendering relief through the distribution of light and shadow involves generalization, through the elimination of insignificant, secondary relief features or the merger of several features into one.

The degree to which relief is generalized on a map must be uniform throughout. This does not means that the

result should be an unfformly dissected relief. On the contrary, a uniform degree of generalization has as its very aim the preservation of the relative degrees of dissection characteristic of distinct regions.

The degree to which generalization is carried depends on the purpose of the map. With reference to the representation of relief by means of contours, the problem has already been treated in various texts and manuals, and is not substantially different as regards the rendering of relief through tinting. We will merely note here some of the guiding criteria which aid in generalizing relief.

For example, one such criterion is provided by the establishment of definite intervals between drainage features. Relief and drainage are closely connected. River valleys and hollows containing or lacking running streams in a dissected mountainous area serve to divide positive features of relief such as crests, spurs, etc. In studying the base map and source maps, it is possible to decide upon certain minimal intervals between stream beds which will be used in defining the mountain spurs separated from one another by hollows. Intervals which are smaller than those decided upon are generalized out, and several spurs may then be merged into one.

However, it may occur that a large number of intervals fail to attain minimal magnitudes and that, as a result, all hollows are generalized out of existence. In such cases, the number of intervals is set for a specific

area according to a fixed scale.

Let us assume that the smallest interval is taken to equal 1 cm. Yet, on the map, the magnitude of the intervals varies or else, within a given distance (let us say, within 5 cm) all intervals are inferior in magnitude to that decided upon. In this case, six hollows separated by five intervals are allowed for this area, while others are eliminated. The map then shows five mountain spurs.

This procedure is entirely applicable in certain mountainous regions, where parallel streams divide mountain spurs, as they do, for example, on the southern slopes of the eastern Caucasus or the western slopes of the Andes in South America. Intervals between hollows are pre-determined either by the editor of the map or by the artist himself, if he has sufficient cartographic training.

In addition, in the course of preparatory work the editor or the artist may single out the hollows and streams to be eliminated by marking them on the base map or the source maps.

An aid to generalizing may be seen in the orographic diagram previously discussed, on which all positive and negative features to be represented in the shadow pattern are indicated graphically. Such a diagram is very useful to artists with relatively little experience in tinting in relief, and is particularly important in tinting in relief on multi-sheet maps to coordinate the shadow pattern of the various sheets.

The setting of intervals and the resulting scale are not intended to be used mechanically, but should be used in a creative manner. In a number of situations, decisions of this type and the scale itself may have be altered as work proceeds on the basis of visual evaluations.

Generalization is acheived by modifying shadows. Some shadows may be entirely eliminated if they pertain to relief features of little significance. Others may be magnified when several features are merged into one, and their intensity may be varied. Intensive shadow serves to single out large, prominent or deep features among minor ones, which are shown by weak shadows.

Experience shows that, regardless of the purpose or scale of a particular map, the procedure for generalization always boils down to the techniques enumerated.

Fig. 40a shows a relief rendered in light and shadow in accordance with the pattern and all the details provided by contour lines. In Fig. 40,b the relief has been generalized through the exclusion of secondary features of little significance. In Fig. 40c, certain features have been marged by means of common shadows. Summits are shown with an intensity equal to that of the passes that separate them (in the lower part of the drawing). In this manner, spurs are represented as a unit, without summits being separated out. This procedure, of course, is not applicable to features in which the relative elevation of summits is greater.

The variation of the intensity of shadows is one of the most frequently used techniques in generalization.

For example, if it is necessary to convey a major orographic trend among secondary orographic features, the features concerned are given shadows of different intensity.

Most frequently, all the techniques enumerated are used in combination with one another.

Generalization is a means for conveying the distinictive features that describe the nature of the relief, and not for consolidating or simplifying relief features. For example, if contour lines indicate a sharply dissected relief with hollows of considerable depth, this characteristic must be preserved in generalization, and the hollow should not be made to appear shallow.

In a polychrome shadow pattern, a further technique in generalization is color variation. Variations in the color background and shadow color, will cause some of the features depicted to be perceived as more prominent and more important than others.

The use of dark shades in shadows, such as dark red or red-brown which, at the same time, are intense, results in an effect of increased elevation. Shadows lighter in color (grey-brown, brown, grey-green) aid in rendering less significant features. Violet and blue-violet tonalities are used in conveying the lowest and deepest features, whose significance does not require that they stand out.

Chapter VI

BASIC RELIEF TYPES AND FEATURES IN CHIAROSCURO REPRESENTATION

42. The legibility of various relief, features in a shadow

pattern.

Relief features of relatively small dimensions (such as various types of valleys: fissures, ravines, canyons, bucket-shaped, V-shaped and U-shaped troughs) do not usually show in a map, unless the scale is very large. On maps of moderate scale, these features become so small, particularly if shadow contrast is lacking, that they cannot be discerned. For example, on maps at 1:5,000,000 and smaller scales, tinting cannot convey such features as the craters of active volcanoes, isolated prominence no larger than 1 or 2 km in diameter, barrancas on volcanic slopes, or erosional furrowns dissecting mountain slopes, unless these features are considerably magnified.

On historical, political and economic maps, the shadow pattern is intended mainly to convey major orographic trends: ranges, steep inclines extending over hundreds of kilometers, and major isolated peaks, which must be magnified. The relative elevation of relief features, as well as the characteristics of crests and summits, do not show. On physiographic and hypsometric maps, in which the shadow pattern often consists of two or more tints and which have, in addition, a color background, the representation becomes such as to allow the recognition of the characteristics typical of the kind of relief depicted: sharp crests and flat watersheds, individual summits and plateaus, terraces, and hilly relief.

The use of light and shadow makes it possible to convey the following basic types of relief:

high altitude mountainous, medium elevation mountainous, low altitude mountainous, hilly, volcanic, plateau, cuesta and plains.

b3. The representation of high-altitude Alpine relief.

The altitude range of high mountain relief in the USSR extends from 1500 m upward.

High-altitude Alpine relief is characterized by the prevalence of sharp rocky crags and peaks, corrie-basins, and bucket-shaped troughs. Some troughs may be modified through erosion to accomodate stream beds.

Usually, high mountain relief consists of an aggregation of large relief features (ranges, masses), separated by river valleys, and smaller features such as those enumerated above. Mountain ranges in a drawing usually have considerable gradients; the steepness of slopes may vary, and will increase from bottom to top. The general outline of mountain slopes from bottom to top will be approximately concave, and vary from spot to spot.

The shadows used in rendering high mountain relief must, above all, serve to emphasize the unity and mass of mountain ranges. This is accomplished by means of shadows which extend from the crest to the foot of the range, covering the shaded side of the range and, at the same time, outlining lateral spurs. The more intense shadows are located near the divides, and are made to weaken downward. Polychrome shadows are the most expressive. By being superimposed over one another as elevation increases, colored shadows gradually grow in intensity and acheive a

heightened plastic effect.

A dark shadow on the shaded side of a mountain range may not always gradually weaken as elevation decreases. The sharpness of a divide is most effectively emphasized by means of a jagged shadow, which is cut off abruptly both in its upper and its lower portions.

The main distinguishing feature of high mountain relief, namely, the altitude of the forms that are part of it, must always be conveyed in its representation. This is best achieved by the use of hypsometric coloration.

The completeness with which the distinguishing features of high mountain relief are conveyed depends, to a large extent, on the scale of the map. For example, on maps at scales of 1:100,000 to 1:500,000, there always exists the possibility of conveying glacial corrie-basins, troughs which cut into one another, and to show details of rocky crags, separate peaks, and so forth. In representing cirques, their upper margins should be emphasized with abrupt lines (Fig. 41). In a number of cases, cirques may be compartmented by low divides, which have resisted erosion. These should be shown by means of top lighting, and their shaded slopes should be shown as darker than the illuminated ones. Linear elements should emphasize rocky crags, areas of cliffs, rocky promontories, and rocky outcrops, both on illuminated and on shaded slopes.

On maps of smaller scale, where all details cannot be conveyed, certain characteristic features (such as

rocky crags) may be shown on an exaggerated scale. Other details are omitted altogether. For example, at a scale of 1: 500,000 many maps corrie-basins become so minute that they cannot be conveyed even in magnified form.

44. The representation of mountainous relief of medium elevation.

Mountainous relief of medium elevation is characterised by relative elevations above surroundig plains of 500 to 1500 m. Relief features are sometimes rocky in nature, but more generally take the form of rounded summits and divides.

Relief of medim elevation may occur in the form of mountain ranges, as well as masses and mountain belts sugemented by longitudinal and transverse river valleys.

Lower absolute elevations than those occuring in high-altitude relief require the use of shadows of lesser intensity in representing them. If three superimposed colors are used in rendering high-altitude relief in its darkest portions, only two should be used at medium elevations.

The rocky areas that may be present in relief at medium elevations are conveyed when the scale of the map allows it. Generally speaking, rocky features are singled out only on large scale maps.

As in the case of high-altitude relief, the main object of the representation should be to convey the unity of the features, their interconnection. For this purpose, higher features are emphasized, cast shadows are made to cover less prominent features, and both river valleys and furrows on the slopes of ranges are conveyed (Fig. 42).

45. The representation of low-altitude mountainous relief.

Low altitude mountainous relief includes mountains from 200 to 1000 m in absolute elevation, with intervening depressions up to 500 m in depth. Low mountains may be in the form of both rounded and sharply defined relief features.

The shadows used to define rounded features of relief should be less intense than those used for mountainous relief of medium elevation. One color is sufficient in rendering shadows. This color should be cooler than that used in mountainous relief at high and medium elevations. In conveying sharply defined features in low-altitude mountainous relief, it is advisable to use two colors, with the condition that the second color, warmer in hue than the first, should not occur extensively in the map.

On large scale maps, in which the relief features depicted assume larger dimensions, it is essential that shadows be used to convey the characteristics of the stream valleys that cut into the watersheds, to show whether they are meandering or straight, broad or narrow. Shadows are then shown either as dark and extending to the bed of the stream, to convey steep banks and narrow gullies, or else as removed at a distance from the stream bed, thereby conveying a broad valley (Fig. 43).

46. The representation of hilly relief.

Hilly relief is a subtype of low-altitude mountainous relief, and consists of isolated hills and ridges separated by rolling or meandering valleys. In conveying it,

emphasis should be given to the isolation of forms, which are not connected in belts or ranges. Hilly relief is expressed mainly on large scale maps, including maps at 1: 500,000 and, more rarely, those at 1: 1,000,000.

Hilly relief is most effectively conveyed through side lighting, with the condition that shadows are applied consistently on all relief features, including flat areas (Fig. 44).

47. The representation of volcanoes.

The typical volcano has the form of a conical eminence. The slopes of volcanoes are often concave in profile, and become steeper as elevation increases. The surface of these slopes are dissected by barrancas, which are ruts caused by running water. Streams may flow in some barrancas. On isolated eminences of volcanic origin, barrancas and the streams they contain are disposed in a radial pattern.

Fig. 45 represents a volcano. It should be kept in mind that, whatever the scale, the representation of a volcano must convey its distinctive features: concave slopes and barrancas. On a large scale map, the network of barrancas will be conveyed in greater detail than on a small scale map, which will require generalization and the representation of only the larger and deeper ruts.

Volcanoes illustrate well the rules governing variations in the intensity of shadows. The summit of the volcano is emphasized with darker shadow, which grows lighter lower down. In a ~~xxxx~~ polychrome rendering, the more intense shadow at the summit ~~xxxxxxxxxx~~ results from an overlay

of three tints, while, as ~~they~~ the shadow weakens at lower elevations, one and then two colors drop out.

One of the more expressive ways of representing a volcano is ~~by~~ through a complete rendering of shadows on all relief features, including plains.

At large scales (1: 200,000 and larger), the craters of volcanoes should also be conveyed. The shadow inside the crater is applied in accordance with the overall side-lighting used.

48. The representation of plateaus and table-lands.

A plateau is bounded by steep slopes, is dissected little or not at all, and is formed of horizontally ~~deposited~~ laid deposits.

A table-land is a raised plain, into which streams have cut deeply.

For all their differences, plateaus and table-lands have traits in common, that justify similar means of representation. They have in common flat surfaces, bounded by moderate or steep inclines. Inclines bounding horizontal surfaces, must rendered by means of vertical or near-vertical lighting, to which a side-light is added. Shadows are shown on the inclines in accordance with the steepness of their grades. At the same time, shadows are intensified or weakened in accordance with their orientation and exposure relative to the cardinal points (Fig. 46). Large scale maps allow a more effective rendering of plateaus and table-lands than small scale maps, since in the latter the gradient of the slopes is so insignificant that the resulting shadows

constitue narrow bands lacking in effectiveness.

49. The representation of cuestas.

Cuestas are asymmetric ridges occuring in formations that have been deposited at an angle and are termed monoclinal. They consist of one stepp slope and one gradual one. Cuestas usually extend in a pattern of parallel ridges. The steep slopes all face in the same direction.

This common orientation allows the use of side-lighting from the same angle for all the ridges. The map must emphasize the overall orientation of the ridges, even though individual eminences may not reflect it. For this reason, the darker shadows of individual features should be applied in the general direction of the ridges (Fig. 47).

The common orientation of cuesta ridges and the asymmetry of their cross section are the essential features of cuestas. These features must be conveyed on all maps. On large scale maps containing a large number of details, the latter should not impair the legibility of these fundamental features.

Shadows that are extended over plains aid in achieving an expressive rendition.

50. The representation of plains.

Erosional and glacial plains share certain features. Both lack eminences of any magnitude, and what eminences they contain are predominantly hammock-like and hilly in nature. Erosional plains are distinctive in being deeply dissected by river valleys.

On small scale maps, such as maps at 1: 1,000,000

and smaller, the shadows that are shown mainly are applied along river valleys and derived from vertical lighting, while other relief features are omitted altogether.

In maps on a large scale, it is quite possible to convey not only the indentations of river valleys, terraces and ravines, but also the rounded forms of divides, which may be shown in light shadow and contrasted with ravines, gullies and other negative features of relief, shown by means of dark shadows and vertical lighting.

Of particular significance is the shadow that covers flat areas. A shadow on a plain makes it possible to convey, by means of side-lighting at the proper angle, all the characteristic traits of plains relief. The sides of terraces, illuminated or in shadow, ravines, emphasized by means of strong shadows, set against a background of smooth, soft half-tones which define hammock-like, hilly features, all contribute to a sculptural depiction of relief (Fig. 48). The principle of consistent illumination in conveying relief receives its most effective application on large scale maps, in conjunction with the use of a background that will convey the effect of atmospheric haze. It is advisable to use two colors for the shadows: a warm hue (brown) for higher features, and a cooler hue (grey-green or blue-violet) for low features. If only one color is used, it should be warm (brown). Monochrome shadow is less effective than dichrome shadow.

51. Conveying the distribution of relief features.

The various patterns in which relief may be segmented

in a horizontal plane, e.g. pinnate, radial, divergent, branching, reticulate and others, differ in the orientation of their component orographic features. To convey these various types of segmentation requires the use of definite kinds of lighting and specific elements of light and shadow.

Fig. 49a illustrates pinnate segmentation. The orientation of the ranges and spurs requires a type of lighting that will emphasize the principal and the secondary spurs.

It is essential to direct the light in such a manner as to have the rays fall at an angle both on the principal range and on the spurs, causing thereby the formation of shadows.

Fig. 49b shows a parallel arrangement of ranges and spurs. Such an arrangement occurs fairly often. In such a case, the choice of a light direction presents no great difficulties. Light may be directed perpendicularly to most orographic features. In addition, however, it is essential that both principal and secondary features be revealed. With this in mind, light direction is chosen so as to cover secondary spurs with shadows cast by the principal range.

A reticulate pattern (Fig. 49c) is distinctive in having longitudinal ranges cross transverse ones, thus suggesting a net. This type of relief requires a light which strikes both longitudinal and transverse features at an angle, causing the formation of shadows on both. At the same time, it is

also essential to reveal the main mountain range.

Fig. 49d shows a branching pattern of orographic features. The orientation of the ranges, that emerge one from behind the other, may be emphasized by means of a common shadow. The light may be nearly at right angles to the orientation of the ranges. It must be kept in mind that the features that require emphasis because of being the highest, need not occur on any one branch, but may be found on several, as shown in Fig. 49d by thickening of the lines. This trait must show up in the shadow pattern, by emphasizing prominent features by intense shadows and causing them to cast shadows.

Fig. 49e represents the rather commonly found radial or star-shaped pattern of segmentation, in which spurs radiate outward from a central summit. This is one of the more difficult subjects to represent by means of shadows. Light from any given direction will strike some spurs at a right angle while being tangential to others, thereby not creating favorable conditions for their representation. It is necessary to vary light direction for some spurs by shifting it sideways. For example, most spurs, with the exception of a and d, will take northwestern lighting. For spurs a and d, a western direction must be used. This will entail cases of both shaded and illuminated slopes facing each other. For example, the shaded slopes of spurs e and d face each other, and this is detrimental to plastic effectiveness.

To counteract this, illuminated and shaded surfaces that face each other should be given differing intensities, one of them being made lighter, the other darker. In doing this, the crests and furrows of the spurs should be emphasized.

In a radial pattern, the central summit is usually the highest. It should be emphasized by means of the most intense shadow, and should cast a shadow in a direction concordant with that of the light.

The extent to which the details of the patterns described above are rendered depends on the scale of the map. At some scales, the rendition may be complete, while at others, their minuteness may prevent their representation.

52. The representation of cliffs.

Cliffs and rocky areas enter into various types of relief.

Cliffs are usually understood to include outcrops of hard materials which have been subject to partial erosion by water, ice, wind action, and so forth.

Cliffs vary in shape. Rocky outcrops in the higher portions of watersheds result in rocky crags, which are sharp, jagged, sometimes terminating in a vertical wall, other times branching out as spurs separated by deep gullies and furrows. On mountain slopes, rocky outcrops show up as peaks, columns, ledges, groups of irregular protrusions, or relatively even surfaces flush with the slope.

The most commonly used means for representing rocky features involves the use of light and shadow executed as a hachured pattern, which allows not only a plastic effect,

but also conveys the sharp and abrupt nature of such features.

- The technique of hachuring in representing cliffs is rather solidly established in cartography.

The necessity of conveying the complexity of rocky features in its entirety is obvious if we consider that, on large scale maps, they are major means of orientation and serve to characterize the extent to which a terrain is passable and defendable.

- The representation of cliffs by hachuring sometimes comes up against the objection that hachures in rocky areas exclude the use of contours and, therefore, prevent estimates of the incline in those areas. The requirement is then advanced that only rocky crests be shown through hachuring, while all other rocky surfaces be expressed in contour lines, without any rendering of cliffs. Some cartographers, though not many, it is true, claim that the depiction of cliffs should altogether be eliminated and replaced by contour lines. The usefulness of such a substitution has yet to be proven.

Experimental work concerning the representation of cliffs, both here and abroad, has aimed at a visually more effective representation of rocky areas, and its integration with contour line representation. The use of polychrome printing processes yields very satisfactory results in this connection. Note should be made, in particular, of the use, on the Swiss map at 1:25,000, of black contour lines on rocky surfaces, as opposed to brown contours elsewhere. Thick black contour lines

~~thicker~~ are likewise preserved in areas of highly pronounced rocky relief, simultaneously represented by hachuring. However, hachuring is distributed in such a manner that a narrow blank margin occurs between it and the contour line. As a result, both the hachuring and the contour pattern are legible.

On small scale maps, the representation of cliffs in the higher mountain regions is desirable to separate them out from among other features of mountainous relief.

Source materials for the representation of maps include maps drawn on a larger scale than the map being prepared, aerial photographs that reveal rocky relief clearly, and information gathered from photographs, drawings, and the literature.

As the map is being prepared, the basic linear elements of rocky relief (such as crags) are first entered on the original. When this is done, it is essential not overload the remaining area occupied by rocky features with contour lines, and to preserve only the thicker ones.

When beginning to draw in rocky features, it is essential first to indicate in pencil the principal and secondary orientations of rocky crags and spurs, and to mark all lines dividing illuminated and shaded areas and outlining areas of further work.

In representing a rocky crest, its sharp, jagged outline is shown by means of hachures. These are, in this case, linear elements extending along the edge

of the crest. In some spots, it merges into shadows on lateral spurs, while in otners it remains a narrow line, marginal to the illuminated and half-illuminated slopes of lateral spurs. In other parts still, it is interrupted to reveal illuminated projections occuring on the shaded slope. The central portion of Fig. 50 shows a crest, with layered outcrops of several formations. The pattern of hachures in that part, oriented vertically, conveys an overall shadow on the crest, contrasting with the illuminated slope and the rocky outcrops on the slopes of the crest. In places where lateral spurs project from the crest, their semi-illuminated and shaded slopes are also shown. Hachures on spurs may be oriented downward, toward the furrows that separate the spurs, but the furrows themselves must be emphasized with hachures paralleling the direction of their drainage. This is very important in showing the spurs. On the illuminated slope of the crest, spurs are shown as having illuminated sides, which are devoid of hachures, and semi-illuminated sides, which are covered with fine hachures. Gullies and furrows are also emphasized by means of longitudinal hachures.

The orientation of hachures may vary. They may be vertical (i.e. extending downward), horizontal (i.e. following the direction of crests) or intersecting. Vertical hachures are usually used to emphasize ledges, precipices and short inclines, while horizontal ones emphasize the extension of the crest in space and its sharp margins in representing both convex and concave features.

Horizontal hachures may convey variations in the exposure of slopes through variations in thickness.

The main concern in hachuring is to convey the degree of illumination of a particular area to ensure the effectiveness of the drawing.

In making simultaneous use of hachuring and contour lines, it is essential to bear in mind the expressive effect desired and to keep evaluating the results visually, since the presence of contour lines eliminates parts of the plastic surface and makes its rendition by means of hachuring somewhat more difficult.

Chapter VII

PREPARING MONOCHROME AND POLYCHROME SHADOW PATTERNS FOR PRINT

53. Technique of preparing a monochrome shadow pattern for printing.

The photomechanical process of reproducing half-tones in print used in modern cartography requires processing of the original. An original shadow drawing may be processed in a number of ways.

The more commonly used procedure in map publication is the preparation of the original on some opaque material for subsequent projection photography. The material is usually paper, mounted on stiff backing (aluminum, plywood) so as to preserve the original dimensions of the drawing. After mounting on stiff material, the contour pattern or other linear elements of the map being prepared are imparted on the paper in blue through photostating or printing. 4/ Photostating has

the advantage that it can be deleted after the shadow pattern has been applied, and that it will not interfere, therefore, with the photographing of the half-tone representation.

Over the blue drawing, the shadow pattern is tinted in. Shading may also be used in executing the original.

Once the shadow pattern has been applied, frame corners or crossed lines are marked on the original to allow the proper application of inks in printing.

Whether tinting or shading is used, it is possible that the photographically-obtained blueprint will show through enough to appear in subsequent printing. In this case, it should be deleted or faded on the completed original by means of potash, ammonia or potassium oxalate. Then, the original should be washed thoroughly for no less than 15 minutes in running water. If, in the course of this treatment, the original is not subjected to mechanical action, such as rubbing with wet cotton, the ink will stay fast and not be washed off.

The original may be executed on transparent material, and then photostated by means of contact-printer. The material used may be vinyl with one mat surface. The original is executed by shading in pencil, and some of the darker spots may be filled with black india ink by means of brush, without any washing over. The process of projection photography then becomes unnecessary, and one of the main causes of size distortion is eliminated thereby.

In executing an original on some transparent material, there is no reason for transferring a blueprint to it. The transparency of the material allows the execution of the drawing by superimposition. The material is then simply laid over the editor's copy, a finished map or a printer's original and secured in place. Angles, crosses and other marks are then drawn on the transparent sheet, to allow the continuous checking of the fit of the sheet over the map, and the shadow pattern is then applied. In map publication transparent originals are still not used widely, because of the lack of a well-developed technology to deal with them.

However, experimental work has shown that transparent materials are susceptible of wide application, and ensure considerable economies of time and a more accurate preservation of the dimensions of the original than non-transparent materials.

A representation on a transparent material may also be obtained by means of tinting. To this end, the material used is not vinyl, but exposed and fixed photographic film on which a layer of gelatine has been preserved. Tinting is done with black or colored non-actinic water-soluble organic coloring agents on the gelatine layer by means of a brush. The washing over of shadows is more difficult than on paper, but reproduced well in print, and may even yield better results if techniques are adequately developed. The resulting representation is reproduced either by means of a contact-printer or a printing frame.

The image obtained on the negative, under normal conditions has the distinctive feature of resolving itself into grains whose dimensions vary with the intensity of shadows in various parts of the image. In areas corresponding to white or transparent portions of the original, fine grains occur, and these form a background which may considerably impair light and shadows contrasts and the quality of the result. To heighten contrast and reproduce the original with greater fidelity, the conditions under which photographic and subsequent processes are carried out are so combined as to eliminate grains in white areas of the original, so that the background disappears. To eliminate background grains, the original is first photographed through a projection grating, and then projected onto the same negative without a grating. This procedure has been described by S.F. Sadchikov*.

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* Instructions for photographic work in the publication of maps and atlases. Moscow, Geodezizdat, 1952.

The procedure of preparing the map for print may sometimes include half-tone retouching on the negative, that may heighten contrast, bring tonal relationships closer to those in the original, and eliminate background grain from the image.

The intensification of shadows on the negative and, in particular, the elimination of background, are done with black or brown water-soluble organic coloring agents by means of a brush and a cotton pad. The negative is secured

on a bench for retouching so that the image does not appear inverted. The coloring agent, strongly diluted with water, is applied with a brush where it is needed, and the excess is wiped away with the cotton pad, which is soaked with water.

Retouching may also be done with a special retouching pencil. The operation should be performed on the emulsion side of the negative. The image will appear inverted, and this makes the work itself and the evaluation of its results more difficult.

To weaken shadows on a negative, the following solution is used:

Red potassium ferrocyanide	2 g
Hypo	15 g
Water	100 cubic cm.

The solution is applied with a brush on the emulsion side wherever shadows must be weakened, and the place is then washed with water with the other end of the brush. If this proves insufficient, the process is repeated.

Half-tone retouching (selective intensification and fading) of the negative is a complex process and requires considerable experience both in tinting relief and in the visual evaluation of a half-tone negative. The dual process of intensification and fading may be reduced to a simple process of intensifying all weak areas on the negative to achieve a tonal relationship approximating that of the negative. Intensification by means of a coloring agent is less complex a process than fading through

the use of potassium ferrocyanide and hypo.

In preparing a tinted original for monochrome printing, it should be remembered that even the most intensely black printer's ink cannot be expected to faithfully reproduce contrasts of light and dark present in the original. Granulation from the grating always lowers contrast somewhat. When printing is in ink other than black, contrast sufferes even more. With this in mind, contrast must be exaggerated in the original. In doing this, of course, the scale and the nature of the map should be taken into account. If, for example, the representation extends over several sheets of a multi-sheet map, contrast should not be made uniform on all sheets, since this would be ignoring possible differences of relief. Contrast should be greatest for the highest features, and decreased for lower ones.

On original executed on transparent material, shadows should vary from completely opaque, filled with bladk india ink or a coloring agent, to translucent, faintly shaded by pencil or tinted with a coloring agent.

54. Techniques of preparing a polychrome representation for printing.

Published maps often involve the representation of shadows in two colors. The preparation of such maps for printing is somewhat different than than of monochrome images. In dichrome printing, two shadow patterns are laid one over the other, overlapping not throughout the entire map, but only in part. The first pattern

consists of long shadows, outlining all relief features. The second pattern which is laid over the first serves to reinforce it only in areas of shadow that emphasize prominent features of relief that occur along crests, at summits, on the sides of gullies and canyons. The two patterns are matched along the shadow edges that border on illuminated areas. On the shaded slopes, the two patterns do not coincide, but, when superimposed, yield areas of maximum intensity that gradually fade at lower elevations, as one color passes into the other.

The preparation of two matching images for printing is done in various ways.

One of these is to prepare one common tinted original, which is photographed twice under different conditions. The first time, a normal or low-contrast negative is obtained, which shows the entire area covered by shadows in the original. The second time, a high-contrast negative is sought, that contains only the darker shadows. These two images are then superimposed in printing. This is termed the "duplex" process. The second image, if it contains shadows that emphasize the higher features of relief, contributes greatly to overall effectiveness when the two images are combined. However, one drawback of the process is that, through photography, the second image is made to contain the darker shadows but not necessarily only those that emphasize the higher features of relief. Dark shadows occur both in high and in low areas. Furthermore, the preparation of the original for the "duplex" process cannot be checked while in progress. The artist can visualize and

evaluate only the compound image he is to produce, and has no way of judging the merits of the two component images separately.

Another process involves, first, the preparation of a tinted original containing all shadows. This original is then reproduced, with strict dimension control, in blue half-tones on a paper mounted on stiff backing. This reproduction reproduces the original completely. A second shadow pattern is then executed on the blue copy. The artist applies shadows, this time, only in those areas where the second color will be used in printing. After the second high-contrast original is completed, the blue image may be deleted. The two images are then matched in the printing process.

The advantage of this process over the preceding is that allows the intensification of shadows only where this is necessary for overall effectiveness, and that it permits visual checking as the work progresses, and that it provides opportunities for introducing changes and corrections.

Two distinct images may be executed on one original. In this case, the images are each in a different color, and may be separated by photographing through color filters. The result is two negatives, corresponding to the two images. For example, the first image, in which all shadows occur, may be executed in a red coloring agent or in red india ink. Once this image is completed, the second one is drawn over it in black india ink, and

contains only the highly contrasting shadows required to reinforce the first image. The original is then photographed twice: the first time without a filter, the second time with xx through a red filter. The first negative contains all the shadows occuring in the original both in red and in black, the second contains only those that occur in black on the original. Two superimposed images result in a more contrasting shadow pattern than is possible with only one color and, furthermore, provide an opportunity for an extensive use of various proportions of color. Dichrome originals are used in cartographic production, particularly in reproducing tinted relief on maps at 1: 500,000. To improve this process, the compositions of indelible coloring agents must be perfected so as to allow the total preservation of the first image after ~~itx~~ it is overlain by the second.

A dichrome pattern may also be executed on a transparent material, such as exposed fixed photographic film. The first image is executed ~~xxxxxxxxxx~~ on the ~~xxx~~ gelatinous layer in red, the second, consisting of highly contrasting shadows, is rendered in black. The resulting original is transferred twice ~~xx~~ on film: the first time without the use of a filter, the second, through a red filter. Two negatives are obtained: one with a complete shadow pattern, the other reproducing only the pattern occuring in black on the original. As a filter, it is possible to use exposed film, colored by means of the same agent as was used in executing the initial red image. An original

executed on transparent material, unlike one on paper, allows the elimination of the photographic projection process. Experimental work bearing on the execution and reproduction of transparent originals has yielded entirely satisfactory results.

Use is also made of three-color shadow patterns on maps, and these make it possible to acheive a high degree of plastic effectiveness.

For the first and second colors, one original is subjected to the "duplex" process. For the third color, it is advisable to execute a separate original over a blueprint obtained from the first original.

In printing a polychrome shadow pattern, shadows with well-defined borders should be matched within limits of 0.2 - 0.3 mm. Otherwise, the image will be perceived as double, and its effectiveness is considerably impaired.

In preparing the originals of a polychrome representation for print, it is very important to separate the overall image correctly into its components, and to have these reproduced without loss as separate originals. The procedures involved in separating a polychrome image into its component colors is best grasped through the execution of polychrome patterns. In producing a polychrome image, the artist must carefully pre-determine relationships between colors so as to facilitate the reproduction of these relationships in separate originals. The preparation of polychrome shadow patterns and the preparation of separate

component images are two processes that are opposite in nature, yet mutually complementary. Without a sure grasp of the techniques involved in producing a polychrome original, in which all color combinations occur in synthetic form, the correct breakdown of an image into monochrome originals is not possible. And only by means of a correct breakdown is it possible to obtain a synthetic polychrome image in print that will conform to the colored original, the sample, or the planned image.

Various countries make use of differing procedures in graphic processing shadow patterns. For example, in Switzerland, in addition to tinting, use is still made of shading, applied directly to the printing die.*

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* An example of the use of shading in a polychrome representation of relief may be seen in the map "Berner - Oberland - Lotschbergbahn - Oberwallis", Masstab 1:75,000, Kümmerly u. Frey, Bern, 1945.

The map publishers in the German Federated Republic make wide use of the photorelief process, which employs terrain models, as perfected developed by the K. Wenschow Company. In the atlas for institutions of higher learning published by K. Wenschow, relief is represented in this manner on physiographic maps.** It should be noted that the same

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** Wenschow - Atlas für höhere Lehranstalten, K. Wenschow, München, 1950.

---

models are used over again for maps at different scales.

The map industry in the USA also makes use of photoreliefs obtained by photographing terrain models. This is the process exemplified in the map of Alaska at 1: 250,000.

Map makers in Czechoslovakia use originals of shadow patterns that are executed through shading by pencil on paper. The drawing is photographed through a grating.

Other countries also make use of all techniques of shadow representation, both those that have been in use for a long time, and those that have gained currency only in recent times. Alongside of tinting and shading, hachuring has not lost its importance and is still widely used. As an example, we may cite a Norwegian school atlas, in which the shadow pattern is executed on maps by means of grey hachuring on a hypsometric background and, in some spots, is reinforced through tinting ***.

*** Nordisk Skolatlas folkskoleupplagan, Ändra upplagan Svenska Bokforlaget, Norstedts, Stockholm, 1951.

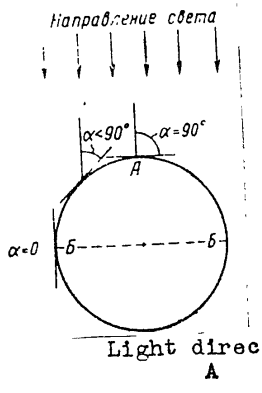
Transparent materials, that are finding ever-increasing application in cartography, may be used in preparing originals of shadow representations. They save time, eliminate certain technical stages, lower the cost of originals, and result in a better grade representation than originals executed on opaque surfaces. However, the techniques involved in their use still need

to be developed. This particular problem requires sustained effort, aimed at promoting the extensive use of transparent materials in map production.

(Illustrations in Koldayev - Plastic Relief)

1. The hachured representation of relief. A portion of a sheet of the map of European Russia at 1: 126,000.

2. The shading of relief.

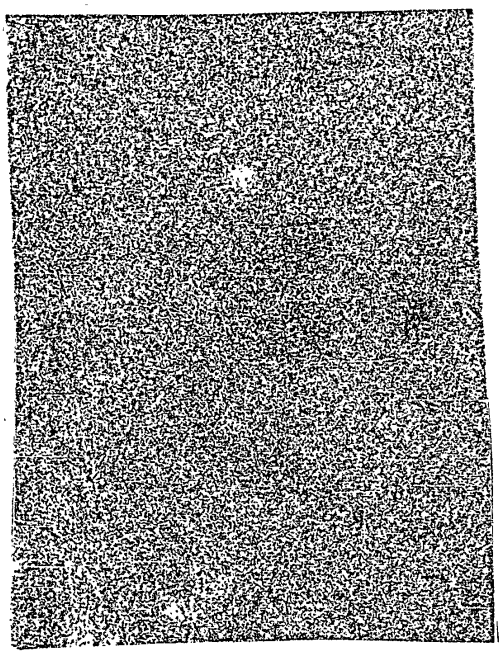


Light direction

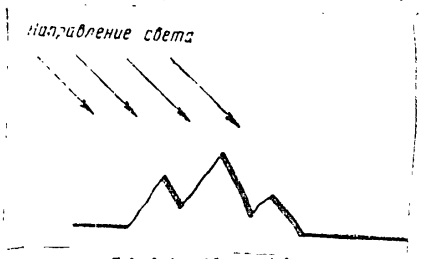
A

B B

Diagram of the illumination of a sphere.

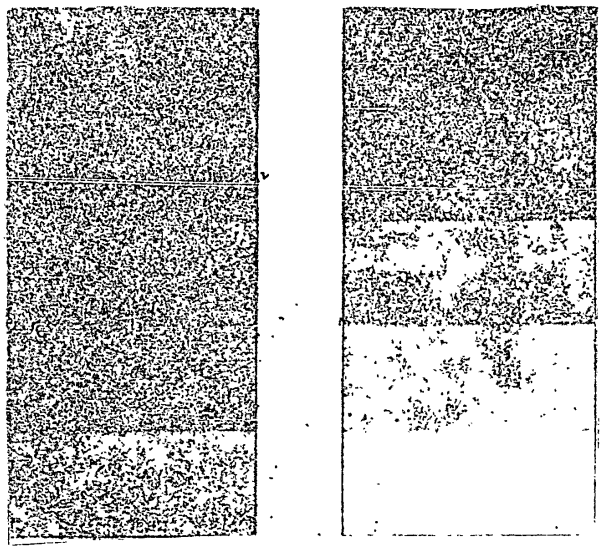


3. The distribution of shadows on a sphere.



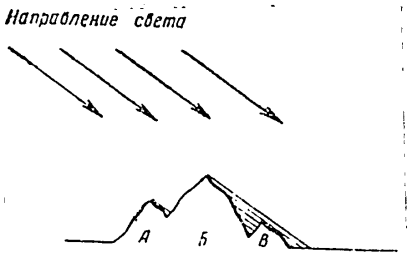
5. Light direction

Diagram illustrating own shadow.



6. A scale of tonal contrast.

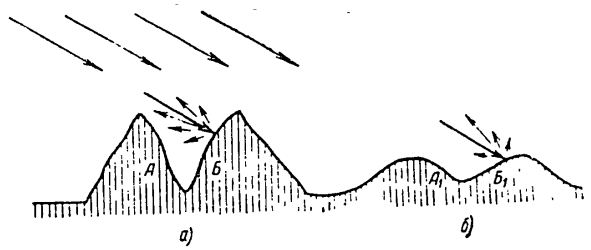
7.. Shadows cast by tall objects.



8. Light direction

A B C

Diagram illust ating cast shadow.

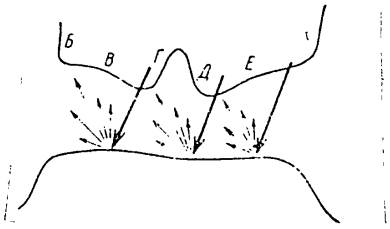


9.

A B A_1 B_1

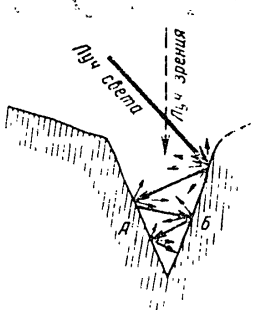
a) b)

Diagram of reflected light in the vertical plane a) Reflected light when angle is small; b) Reflected light when angle is large.



10. Diagram of reflected light in the horizontal plane

B C D E F G

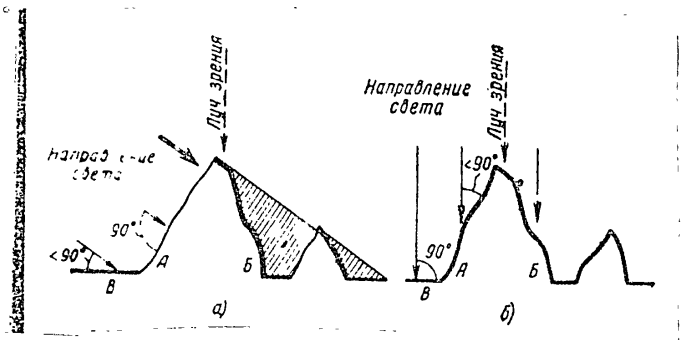


11. Line of sight

Light ray

A B

Diagram showing light scattering and reflection in a concavity.



12. Line of sight

Line of sight

Light direction

Light direction

A B

C

a)

A B

C

b)

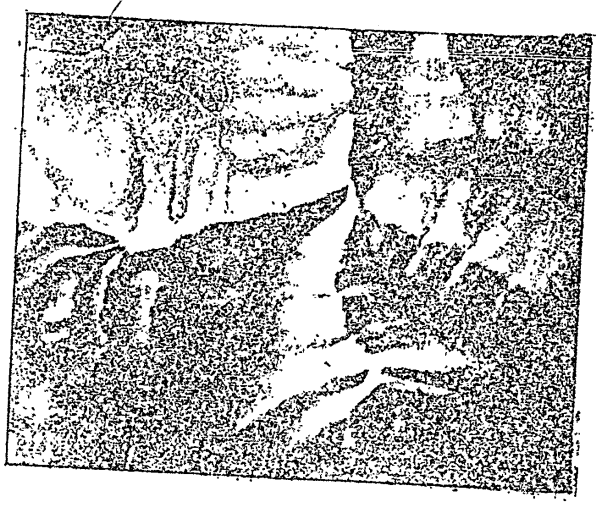
A comparison of ~~illumination~~ the illumination of surfaces under side- and top-lighting.

a) side-lighting b) top lighting

и вершины не являются границами раздела освещенных и теневых поверхностей, поэтому их выступление воспринимается очень слабо.

Все эти особенности не создают условий для ... видения объемных форм, особенно горного рельефа ... Тяжелый рельефа, равнинного или слабо всхолмленного, ... гами с плоскими или куполообразными водоразделами ... освещение создает более благоприятные условия. На ... щенными в этом случае являются крутые склоны оврагов и ... Темные тени передают их выпуклую форму на светлом фоне тех, обрисовывающих пологие склоны куполообразных холмов.

Боковое освещение при его последовательном размещении позволяет передать в изображении формы любого рельефа, в том числе равнинного и слабо всхолмленного. На ... видно, что поверхность *B* представляющая равнину, ... меньше, чем поверхность *A*, на которую лучи света ... ярко



13. The representation of relief by means of shadows.

Shadows are given for all relief features.

ченные участки на берегах рек, холмах ... других возвышенностях в соответствии с их освещенностью. ... фотографии рельефных моделей, полученные при ... освещ-

...нии, все [illegible] можно видеть, что равнины на [illegible] них выглядят более темными, чем склоны, обращенные к свету. Эффект объемности теневого изображения обязан главным образом последовательному применению бокового света для всех поверхностей (рис. 13).

Однако на [illegible] картах боковое освещение большей частью применяется не для всех поверхностей, а лишь для форм горного рельефа. Причина [illegible] в том, что при боковом свете необходимо равнины закрыть [illegible] более или менее темной тенью, на фоне которой снижается [illegible] всех остальных элементов карты.

Вместо [illegible] равнины оставляются без тени, а освещенные склоны [illegible] показываются [illegible] участках светлой тенью, уменьшающейся [illegible] к верху (рис. 14). Этот прием осно-

14. The repr:sentation of relief by means of shadows.

Shadows are given only for mountainous relief.

ван на различии [illegible]
в глаз от нижних и верхних участков освещенных горных склонов. Свет, отраженный нижними участками, проходит до глаза более длинный путь, чем свет, отраженный верхними участками, и испытывает большее влияние рассеивающей среды — атмосферы, ослабляющей свет. Однако этот прием также требует, чтобы и равнины были закрыты тенью вследствие рассеивания света, что в изобра-

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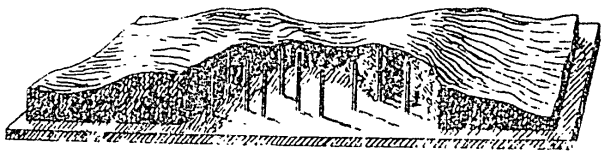
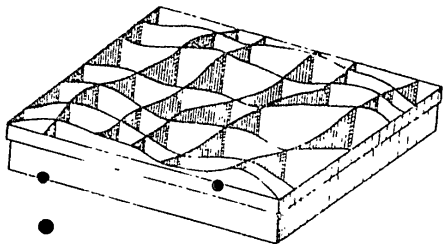
На фанерном основании или деревянной доске наклеивается карта или рукописная копия с нее с изображением рельефа горизонталями и отметками высот. На этой основе в характерных точках (долины рек, гребни, вершины, ровные участки впадин, подошвы гор, водоразделы и т. д.) устанавливаются металлические стержни, представляющие высотную основу. Стержнями могут служить куски достаточно толстой проволоки или гвозди. Стержни забиваются так, чтобы над основанием они поднимались на высоту



15. Elevation armature ~~xxxxxx~~ of a model, constructed of stakes.

ским материалом: глиной с песком, пластилином гипсом, папье маше и т. д. Все неровности между стержнями формуются глазомерно (рис. 15).

Бо́льшую точность в передаче рельефа позволяет дать высотная основа, состоящая из вертикальных профилей, построенных по

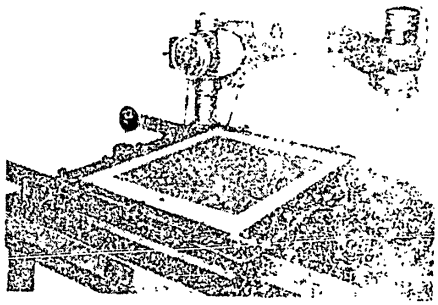


16. Elevation ~~xxxxxxx~~ armature of model, constructed of cross sections.

характерным точкам или взаимно перпендикулярным направлениям. Профили, вырезанные из фанеры или картона, наклеиваются на основу перпендикулярно к ее поверхности или врезаются в нее. Промежутки между профилями так же, как и между стержнями, заполняются материалом и формуются на глаз (рис. 16).

17. A tiered relief model.

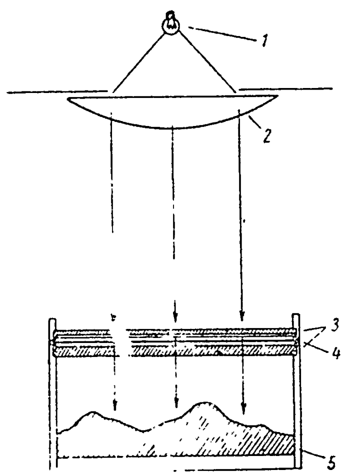
18. A three-dimensional pantograph, used in preparing relief models by milling.



19. The reliefograph, used in preparing models from sheet metal.

50

Лучи света выходя из л[illegible]зы, [illegible] в параллельный пучок. Тени от горизонталей [illegible] на модель должны совмещаться с [illegible]лениями модели. В случае [illegible] выступающие части на модели [illegible]ращиваются [illegible]. Размер получаемого теневого изображения в гор[illegible] [illegible]деляется размерами [illegible] бл[illegible]ение не [illegible] Та[illegible] [illegible]овести ко[illegible] корректуру боль[illegible] модели [illegible] обходимо при[illegible] [illegible] больших размеров [illegible] позволяла проекти[illegible] тени на [illegible] модель [illegible] по частям.



20. **Diagram of shadow projector: 1 - point light source; 2 - lens; 3- glass; 4 - positive of contour pattern; 5 - model.**

Тен[illegible] горизонтал[illegible] также дают возможность [illegible]полнять [illegible] модель необходимыми [illegible]тями, которые не [illegible] [illegible]жаются в процессе [illegible] модели [illegible] [illegible] [illegible] требиями [illegible] курган[illegible] [illegible]

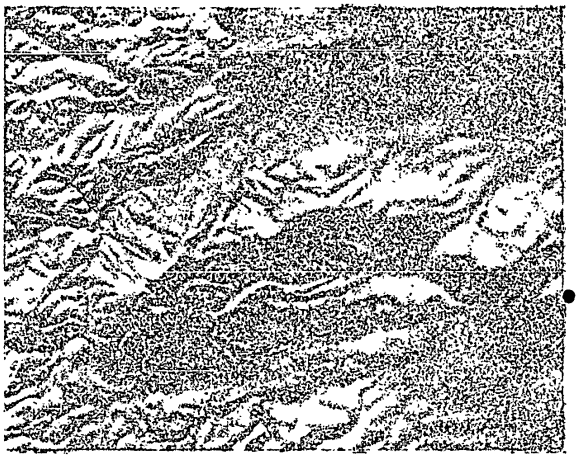
П[illegible] контроле рельефа [illegible] необходимо обоб[illegible] выделяемые и [illegible] детали. Следует [illegible] необходи[illegible] [illegible] [illegible] [illegible]

Б[illegible] модел[illegible]ровке [illegible] [illegible] [illegible] помогающие [illegible] переделать рельеф.

Для контроля [illegible]лаженной модели [illegible] [illegible] темный [illegible] (черный [illegible]). При [illegible] [illegible] при заполнени[illegible] [illegible] темные [illegible] в виде линий на высту[illegible] [illegible] должны совпадать с тенями от горизонталей [illegible] [illegible]вом [illegible]оекторе.

Пове[illegible]хность [illegible]лаженной модели обычно [illegible] трещины и требует шпаклевки. Шпаклевка производится [illegible] мела со [illegible] или малярн[illegible] [illegible] шлифуется [illegible] [illegible]ной шкуркой [illegible] таким образом, чтобы [illegible] не были [illegible] [illegible]тены

ся блики. Хорошие результаты дает окрашивание торцевой частью щетинной кисти («в набивку») или аэрографом, позволяющими получить матовую поверхность.



21. Photorelief.

На предприятии К. Вечнова (ФРГ) могут перед фотографированием покрываться алюминиевой краской, что позволяет получить на фотографии резкие тени. Структура частиц алюминия должна быть такова, чтобы поверхность оставалась матовой.

При изготовлении фоторельефа с печатаемого с карту на поверхность модели, ориентируясь по формам рельефа, наносят подробную речную сеть, границы, дороги, населенные пункты и надписи, снова все элементы декоративного оформления заголовок карты.

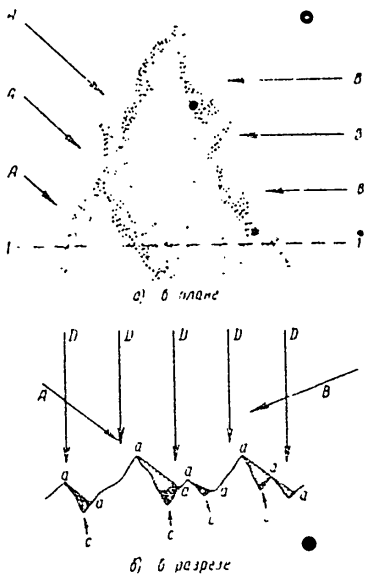
Полученный фоторельеф дополняется цветными элементами карты: покрывается синим различными цветами водные бассейны, голубым цветом ледяные массивы, зеленым, коричневым суша, как это и т. д.

При изготовлении фоторельефа для запечатывания готового изображения на карту содержание карты на модели не вносится.

Воспроизведение всей гаммы теней фоторельефа требует высокого качества печати. Положительные результаты дает способ фотопечати, позволяющий получить изображение с меньшими потерями в тенях.

Фотографирование модели требует применения специальной осветительной установки, позволяющей направлять на модель лучи света наиболее выгодно.

В практике экспериментального фотографирования моделей применялась обычная двусторонняя осветительная установка, имеющаяся при репродукционных фотоаппаратах. При фотографировании модели одна лампа выключается, а другая помещается так, чтобы свет падал на модель сбоку под установленным углом и с определенного расстояния. Угол и расстояние определяются опытным путем, исходя из того, чтобы не было слишком длинных падающих теней и свет равномерно распределялся по поверхности модели.



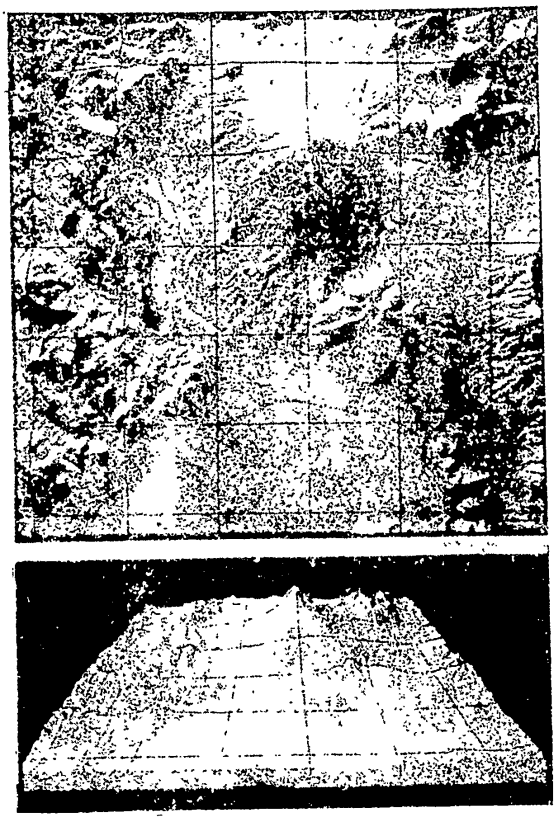
При отношении масштабов, равном 1, такая осветительная установка позволяет получить фоторельеф, в котором тени достаточно выразительно рисуют рельеф, но в то же время обладающий существенными недостатками: все тени выглядят слишком резкими, отсутствует полутоновая дегалировка

22. A B
A B
A B
a) plan
b) cross section

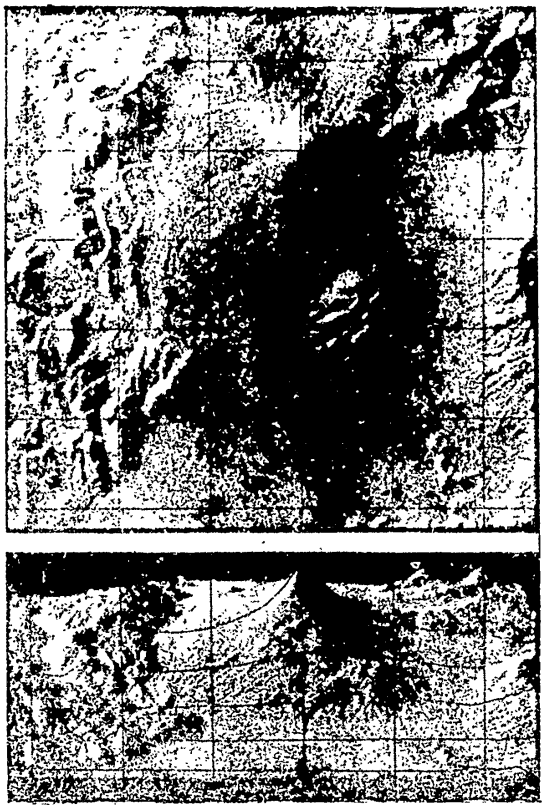
ных тенях, за-
их крупные фор-
фа. Это объяс-
действие отра-
щем рельефные
осветительная
ета.

Lighting diagram for photographic model.

боку наклонные
в углублениях ниже линии *аа*
(рис. 22,б) выступают глубокие тени, в которых структура рельефа
не читается. Второй источник света, посылающий также наклонные лучи света *ВВ*, ослабляет глубокие тени, но не полностью. Темные тени остаются в глубоких лощинах и впадинах *сс*. Поэтому при-



23. Photograph of model in central projection (reprinted from the Journal "Photogrammetric Engineering", 18, No. 3, June 1952).



24. Photograph of model in parallel projection (reprinted from the journal "Photogrammetric Engineering", 18, No. 3, June 1952).

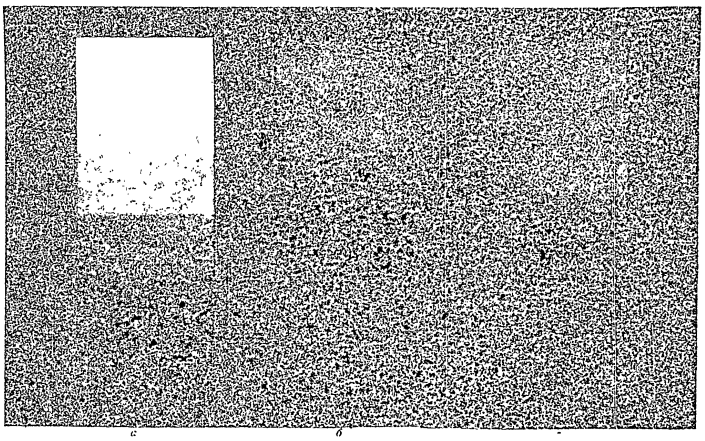


Рис. 25. а b c

Variations in brightness and intensity. a) achromatic and b) chromatic series of varying brightness, c) variations in intensity at constant brightness.

Courtesy of the General Research Institute of Geodesy, Aerial Photography and Cartography, 1956.

26. Hypsometric coloration according to the principle "the higher the elevation, the darker the color"

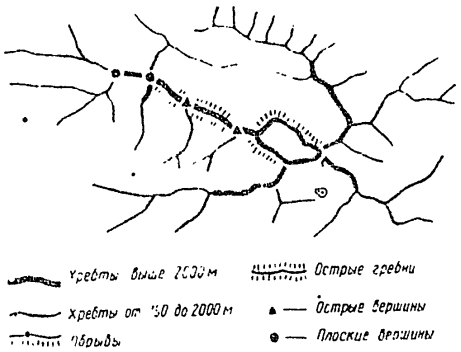
Courtesy GRIGAPC, 1956

27. Hypsometric coloration according to the principle "the higher the elevation, the lighter the color"

Courtesy CRIGMPS, 1956

речную сеть, дополнив ее элементами гидрографии, перенесенными с картографических источников, и затем уже наносить элементы орографии. Гидрография закрепляется карандашом лишь на тех участках, где рельеф показывается отмывкой. Там же, где отмывка не применяется (например, на равнинных территориях), следует нанести речную сеть лишь по необходимости.

Орографическая схема может иметь различный характер. Например, если горизонтали достаточно ясно намечают водоразделы и изображение сильных склонов, нет надобности вносить их подробно карандашом. Для этого случая орографическая схема может содержать лишь основные структурные линии, которые не показаны четко горизонталями и на



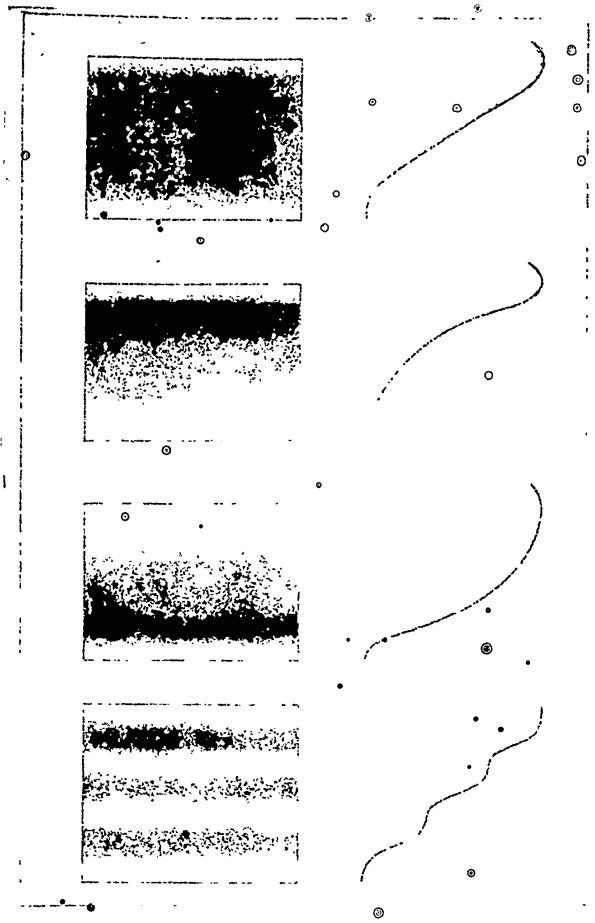
28.

Ranges above 2000 m	Sharp crests
Ranges from 750 - 2000 m	Pointed summits
Sudden drops	Flat summits

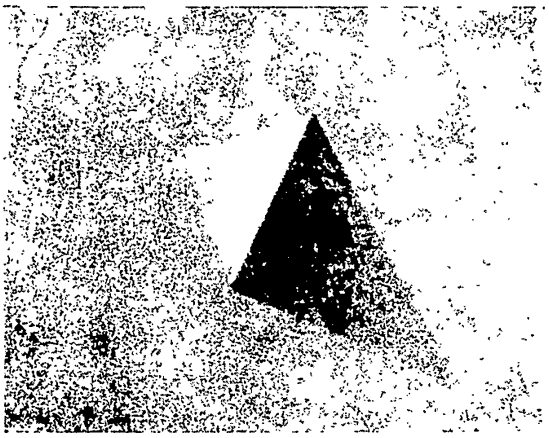
[illegible] все они, наравне с элементами речной сети, необходимы в процессе дальнейшей работы по наложению сеток.

Пример составленной орографической схемы на картографической основе дан на рис. 2е.

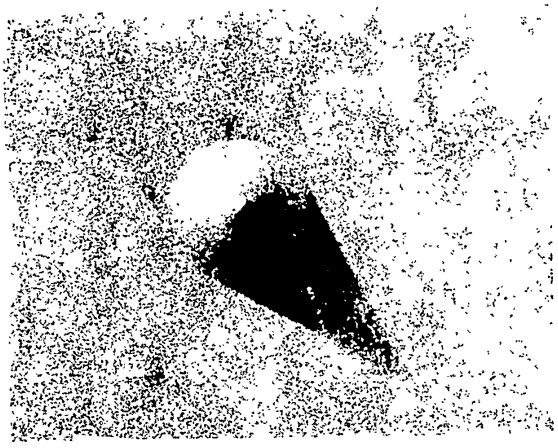
В производственных условиях орографические схемы составляются непосредственно исполнителем и на них показываются лишь те элементы, которые исполнитель считает для себя необходимыми. Было бы целесообразно организовать составление общей орографической схемы для всех горных систем Земли, например в масштабе 1:1 000 000. Подобная схема могла бы послужить



29. Shadow patterns on slopes of varying profile.

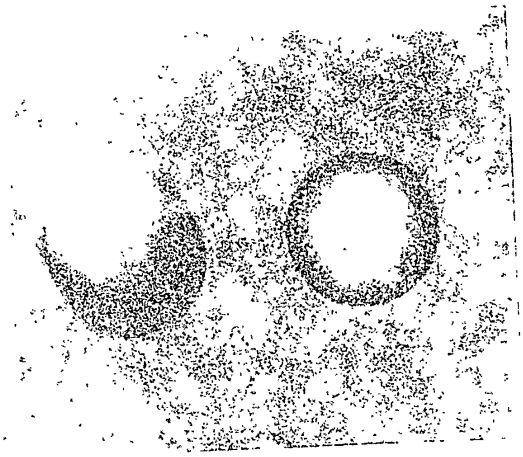


30. Shadows on a pyramid.



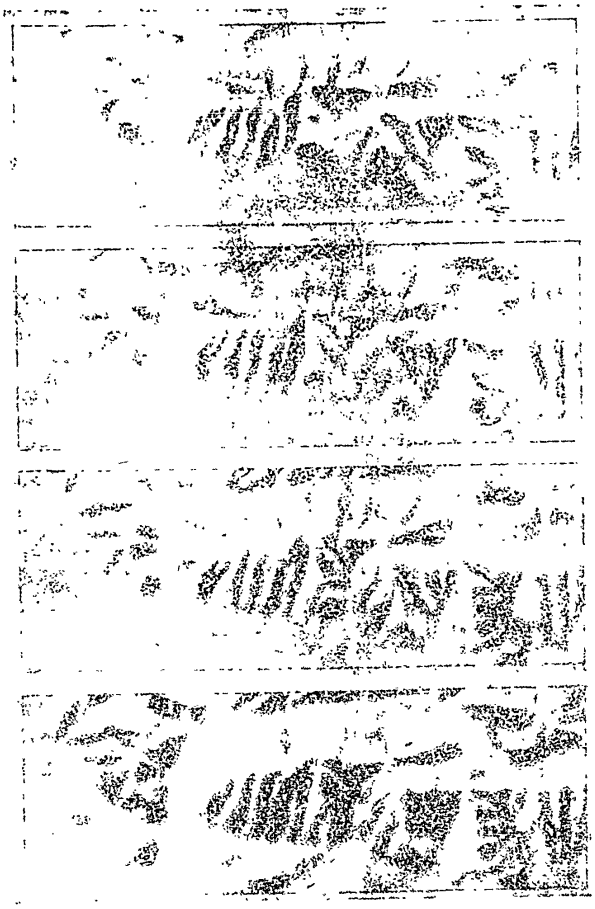
31. Shadows on a ocean

32. Shadows on a prism.



33. Shadows on a hemisphere.

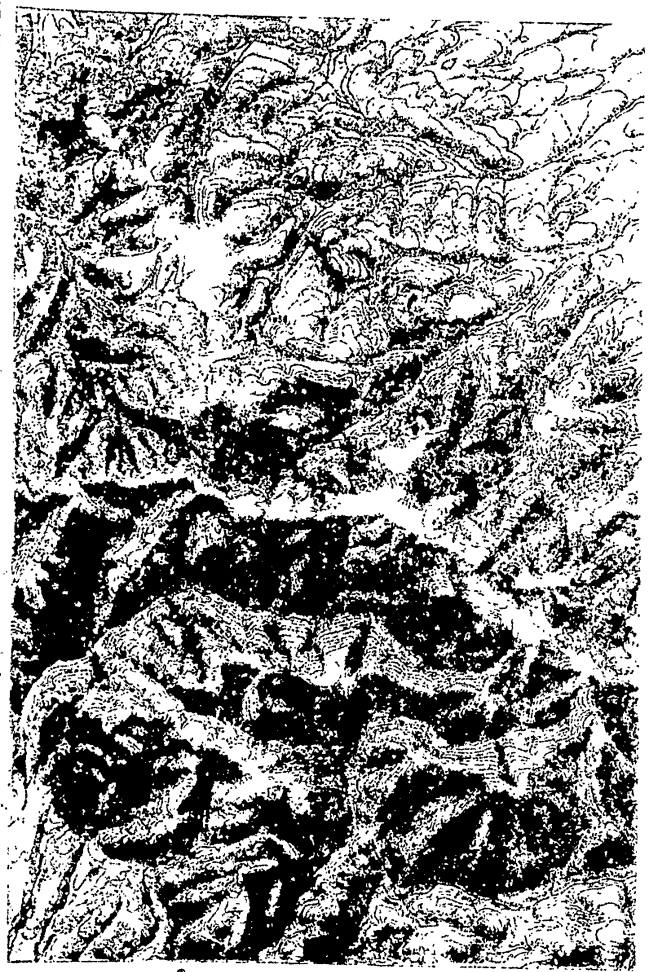
34. Geometric shapes, filled in with details characteristic of relief features.



35. Phase by phase sequence of application of shadows.

36. Sequence in representing relief in color. The color background. Courtesy CRIGC, 1956

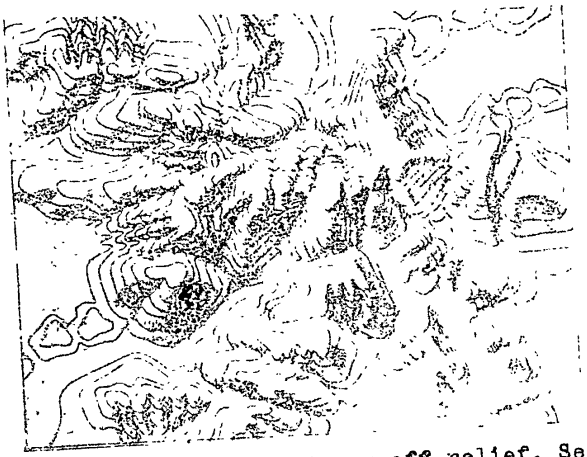
37. Sequence in representing relief in color. The application of shadows in color No. 1. Courtesy CRIGC, 1956



38. Sequence in representing relief in color. The application of shadows in color No. 2. Courtesy CRIG, 1956

39. Sequence in representing relief in color. The application of shadows in color No. 3. Courtesy CRIGC, 1956

40-a Generalizing features of relief. A shadow pattern executed in detail in accordance with contour lines.



40-b Generalizing features off relief. Secondary feature have been eliminated.

40-с Generalizing features of relief through merger.

лозначимых форм. На рис. 40, *в* некоторые формы рельефа объед
ены общей тенью. Вершины показаны одинаково интенсивно
разделяющими их седловинами (в нижней части рисунка). Так
образом, отроги показаны целиком без выделения вершин. Подо
ный способ обобщения, конечно, не относится к тем формам,
превышение вершин над понижениями является большим.

Изменение интенсивности теней является одним из наибо
часто применяемых приемов в обобщении. Например, если в и
бражении необходимо передать главное орографическое напр
ление среди второстепенных элементов орографии, то все они
деляются различной интенсивностью тени.

Чаще всего все перечисленные приемы обобщения пр
няются в сочетании друг с другом.

Обобщение служит средством для передачи особенностей,
ределяющих характер рельефа, но не для того, чтобы укруп
и сглаживать формы рельефа. Например, если горизонтали рис
резко расчлененный рельеф с значительно углубленными про
нами, то необходимо при обобщении сохранить их характер,
превращая их в пологие ложбины.

В многоцветном теневом изображении, кроме всех перечи
ных приемов, средством обобщения является изменение цвет
зависимости от цветовых изменений в цветном фоне и тени

На картах более мелких масштабов, где невозможно передать все подробности, характерные черты (скалистые гребни) показываются в преувеличенных размерах. Некоторые детали вообще не показываются. Например, на картах масштабов мельче 1 : 500 000 многие кары принимают настолько мелкие размеры, что передать их в этом масштабе не представляется возможным даже при увеличении размеров.

41. High mountain relief.

§ 44. Изображение среднегорного рельефа

Среднегорный рельеф характеризуется относительным превышением форм рельефа над прилегающими равнинами в пределах 500—1500 м. Формы рельефа в ряде случаев имеют скалистый характер, но чаще это выравненные округлые вершины и водоразделы.

Среднегорный рельеф может протягиваться в виде хребтов, а также располагаться массивами или горными цепями, разделенными продольными и поперечными речными долинами.

Более низкие высоты, чем в высокогорном рельефе, обязывают применять в изображении менее интенсивные тони. Если для передачи высокогорного рельефа применяют три краски, накладываемые одна на другую в наиболее темных местах, то в среднегорном рельефе достаточно двух красок.

Скалистые участки, встречающиеся в среднегорном рельефе, выделяются там, где это позволяет сделать масштаб карты. Главным образом, скалистые формы выделяются на картах крупных масштабов.

42. Medium-elevation m untainous relief.

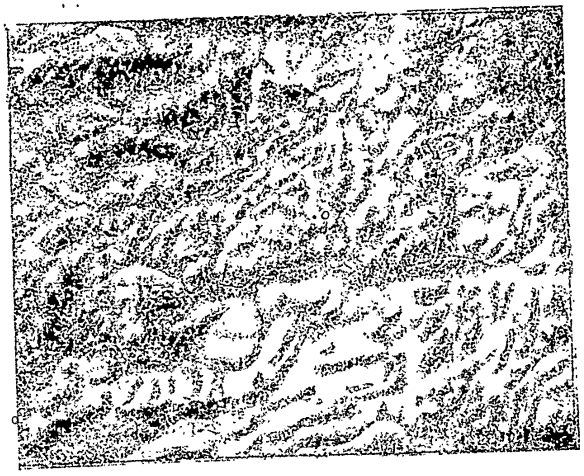
Как и в высокогорном рельефе, основное в изображении — это передача монолитности форм, связанности их между собой, цельности. С этой целью подчеркиваются наиболее высокие формы, дается падающая тень, закрывающая менее высокие формы, выражаются речные долины и борозды по склонам хребтов (рис. 42).

§ 45. Изображение низкогорного рельефа

К низкогорному рельефу относятся горы от 200 до 1000 *м* абсолютной высоты с глубиной расчленения до 500 *м*. Низкие горы могут складываться как округлыми, так и резкими формами рельефа.

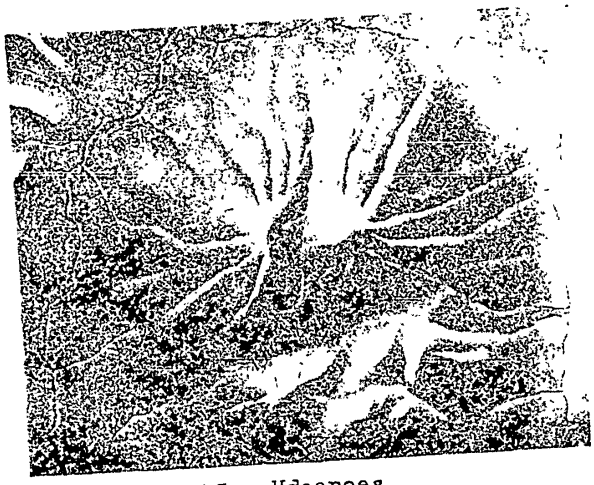
Тени, подчеркивающие округлые формы рельефа, даются менее интенсивными, чем в среднегорном рельефе. Для теневого изображения достаточно применения одной краски. Цвет тени более холодный, чем в изображении высокогорного и среднегорного рельефа. Для передачи резких форм низкогорного рельефа целесообразно применять две краски, учитывая, что вторая краска, более

43. Low altitude mountainous relief.



44. Hilly relief.

На картах крупных масштабов (1 · 200 000 и крупнее) в изображении также передаются кратеры вулканов. Тень на кратерах накладывается, исходя из общеустановленного направления бокового света.



45. Vdcanoes.

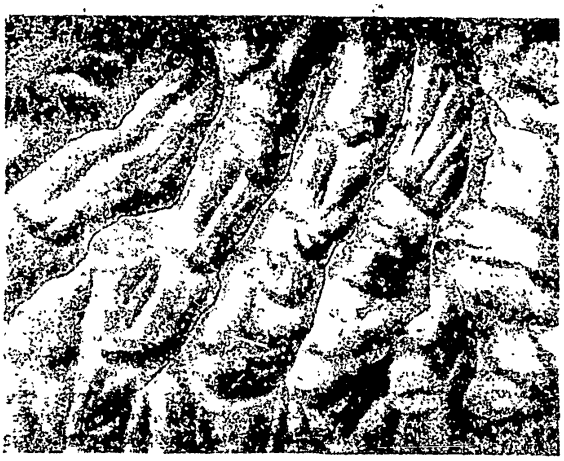
§ 48. Изображение плато и плоскогорий

Плато ограничено крутыми обрывами, мало или почти не расчленено, сложено горизонтально залегающими породами.

Плоскогорье представляет поднятую равнину, в которую глубоко врезаны реки.

При значительной разнице плато и плоскогорья имеют общие черты, которые позволяют искать сходные способы изображения. Общим является наличие горизонтальной поверхности, ограниченной пологими или крутыми склонами. Склоны, ограничивающие горизонтальные поверхности, изображаются при отвесном или близком к нему освещении, к которому примешивается боковой свет. На склонах даются тени в зависимости от их крутизны. Однако в соответствии с ориентированием склонов по сторонам горизонта тени усиливаются или ослабляются при изменениях экспозиций склонов (рис. 46). На крупномасштабных картах имеется возможность более выразительно передать плато и плоскогорья, чем на мелкомасштабных картах, так как на последних заложения

46. Plateaus and table-lands.



47. Cuestas.

фоном, передающим эффект воздушной дымки. Для теней целесообразно применять два цвета теплый (коричневый) для более высоких форм и холодный (серо-зеленый или сине-фиолетовый) для низких форм или же один теплый (коричневый). Одноцветная тень дает меньший эффект, чем двухцветная.

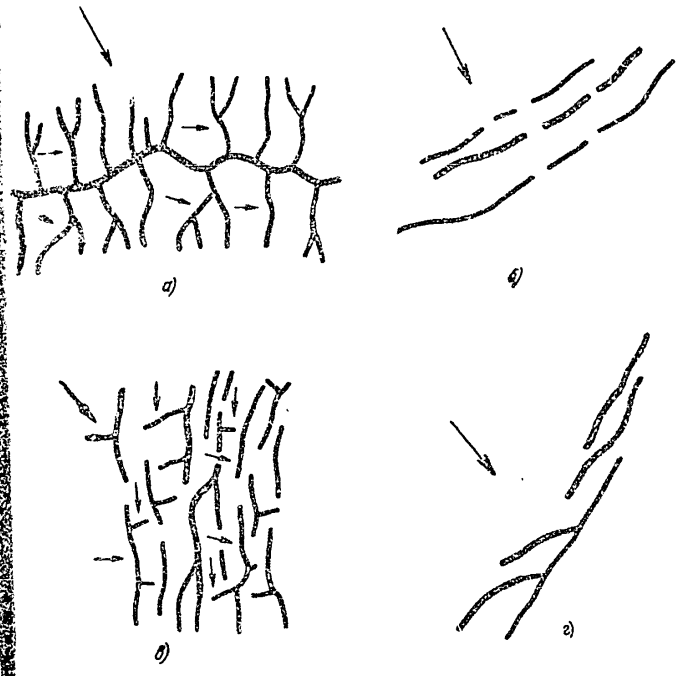
48. a) b)
~~Fig~~ A plain.
a) wide-lighted b) top-lighted.

Различные типы горизонтального расчленения горного рельефа: перистое, радиальное, виргации, кулисное, решетчатое и другие отличаются различным направлением элементов орографии. Передача различий расчленения требует определенного освещения и применения определенных элементов светотени.

На рис. 49, *а* представлено перистое расчленение. Направление хребтов и отрогов требует освещения, подчеркивающего и главный и второстепенные отроги.

Необходимо свет направить так, чтобы лучи одновременно падали под углом как на главный хребет, так и на отроги, вызывая образование теневых поверхностей.

Рис. 49, *б* изображает параллельное расположение хребтов и отрогов. Подобное расположение встречается довольно часто. В этом случае выбор направления света больших затруднений не



49. a b
в г
е

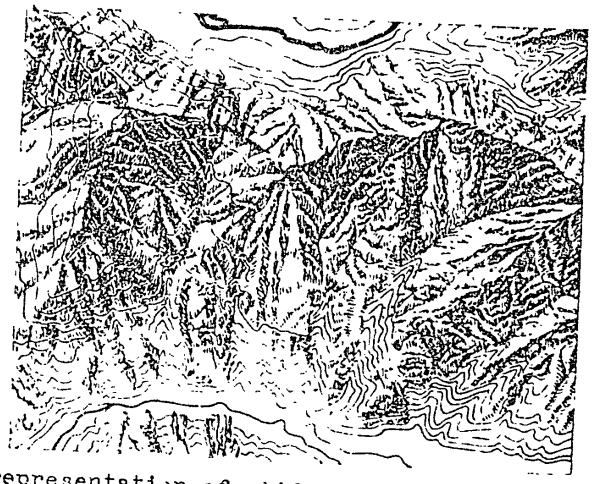
Light directions for tinting in various patterns of relief segmentation: a) pinnate; b) parallel; c) reticulate; d) branching; e) radial.

Материалом для изображения скал являются карты масштабов более крупных, чем масштаб составляемой карты, аэроснимки с отчетливым изображением скалистого рельефа и сведения, почерпнутые из фотографий, рисунков и литературы.

Еще в процессе составления карты основные линии скалистого рельефа (например, скалистые гребни) наносятся на оригинал. Но тогда же необходимо остальную площадь, занимаемую скалами, загружать не всеми горизонталями, а только утолщенными.

В начале рисования скал необходимо карандашом наметить основные и второстепенные линии скалистых гребней и отрогов, а также выделить все линии, являющиеся границами света и тени и определяющие дальнейший процесс рисования скал.

При изображении скалистого гребня острый зазубренный характер его передается штрихами. Это обычно линия, протягивающаяся вдоль края гребня. В одних местах она переходит в тени на боковых отрогах, в других местах остается тонкой линией, граничащей с освещенными и полуосвещенными склонами боковых отрогов, в некоторых же местах прерывается, открывая освещенные



50. The representation of cliffs through hachuring.

выступы, расположенные на теневом склоне. На рис. 50 в центральной части представлен гребень с прослойками выходов различных пород. Система штрихов в этом месте, расположенных вертикально, передает общую тень на гребне, контрастную с освещен-